

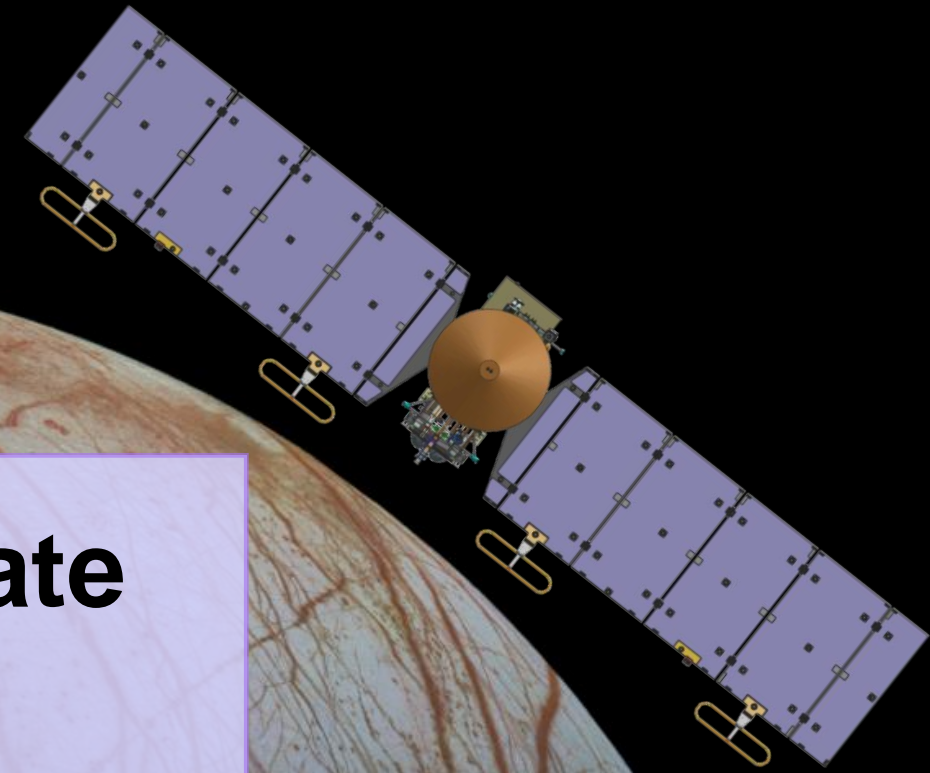


Europa Clipper Mission Update

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*Jet Propulsion Laboratory,
California Institute of Technology*

Karen Kirby, Nori Laslo
*Johns Hopkins University
Applied Physics Laboratory*





Europa Clipper Mission: Overview



Topics

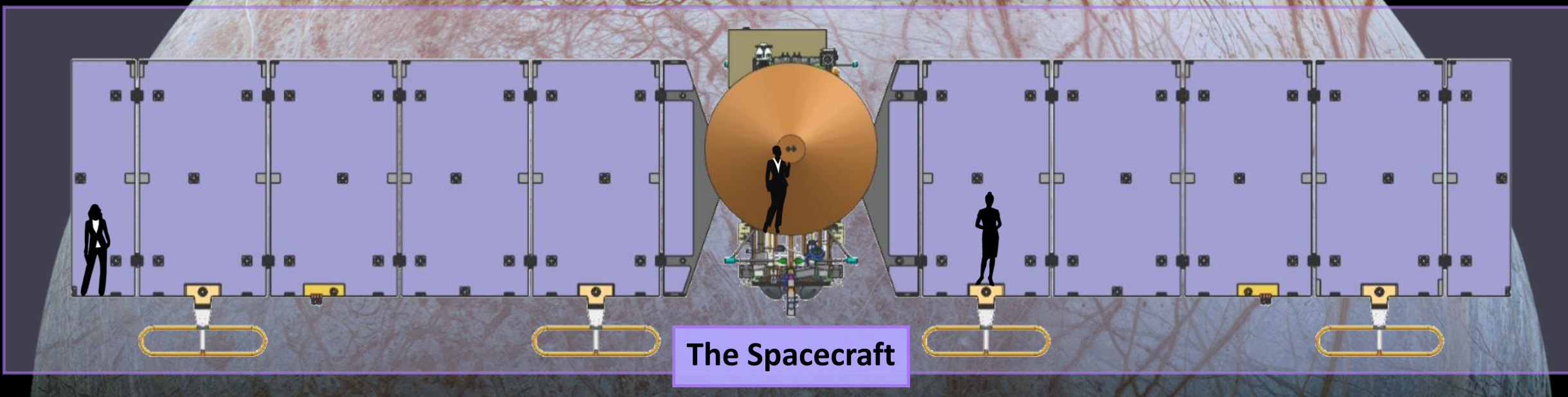
- Mission Recap
- Science Recap
- Mission Challenges
- Selected Updates
- Future Work

The Mission

Destination: Europa, Moon of Jupiter
Launch Date: June, 2022 →
Travel Time: ~3 or ~6 years
Instruments: 9
Mass: 5000 kg (2550 kg unfueled)
Purpose: Assess the potential habitability

The Target

Name: Europa
Location: Orbiting Jupiter
Distance: ~5 – 5.5 AU
Size: slightly smaller than Earth's Moon
Supports Life: unknown



The Spacecraft

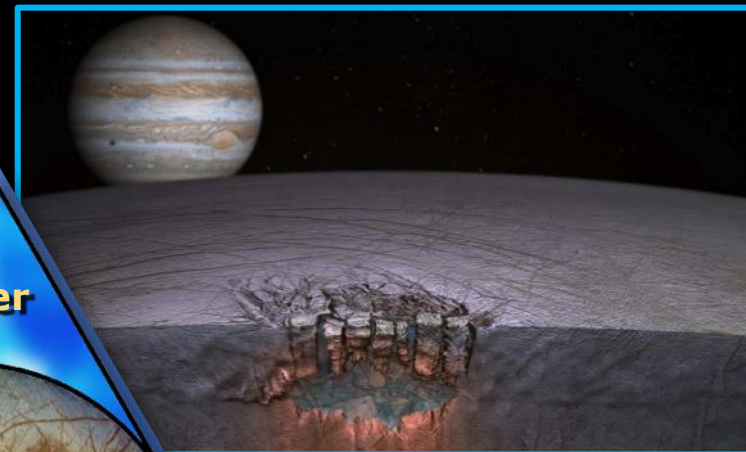
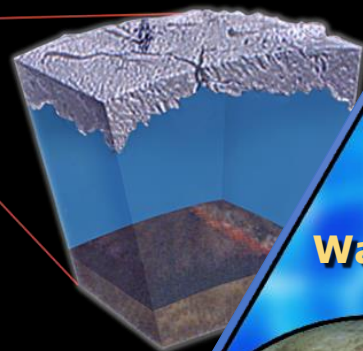
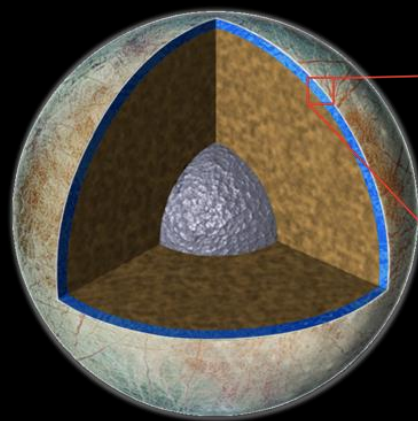


Why Investigate Europa?

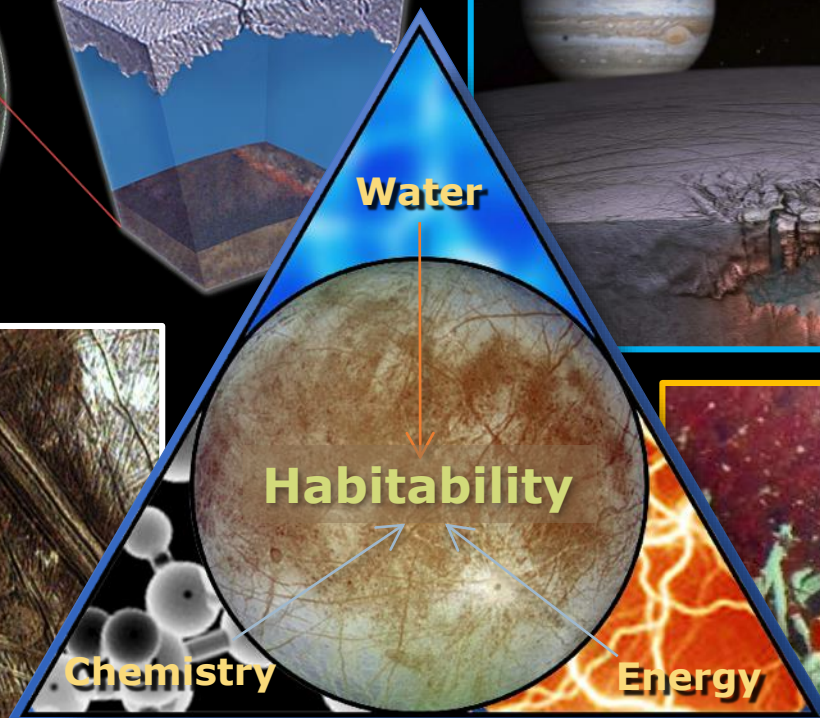


The Search for Life

Water: Are a global ocean and lakes of water hidden below the ice?



Chemistry: Do red surface deposits tell of habitability below?



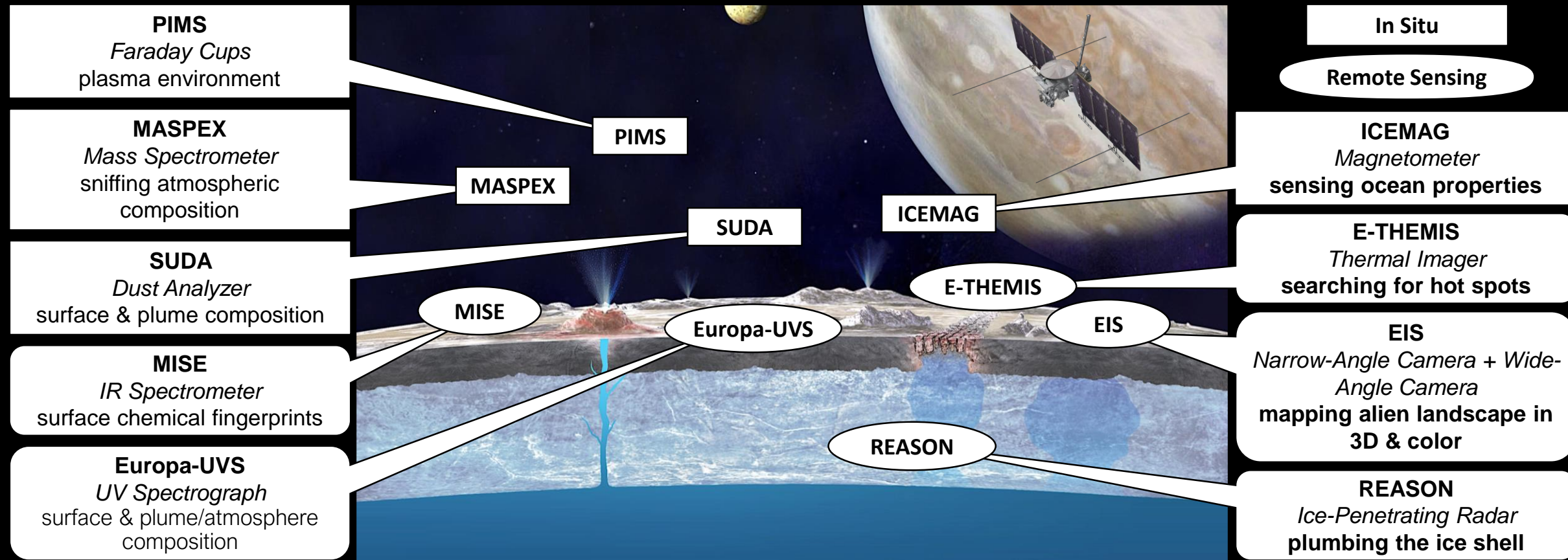
Energy: Can chemical disequilibrium provide energy for life?



The Europa Clipper Instruments

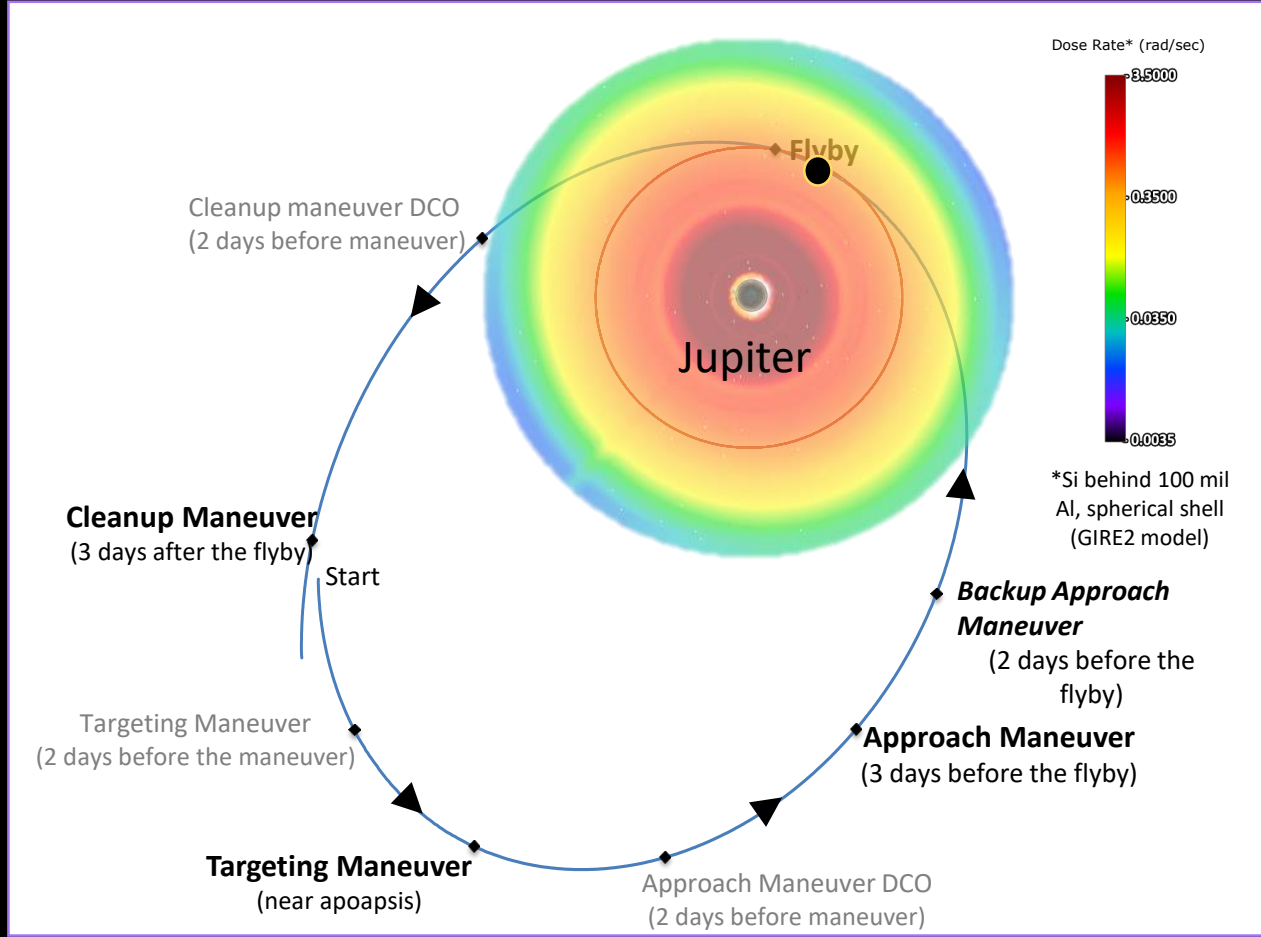


Payload specifically designed to assess habitability





Challenge: Radiation

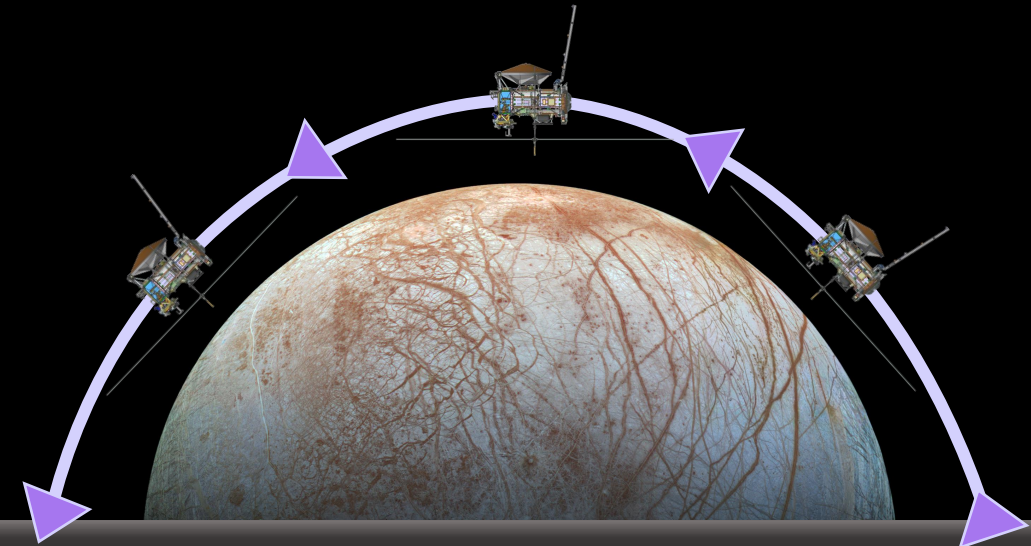
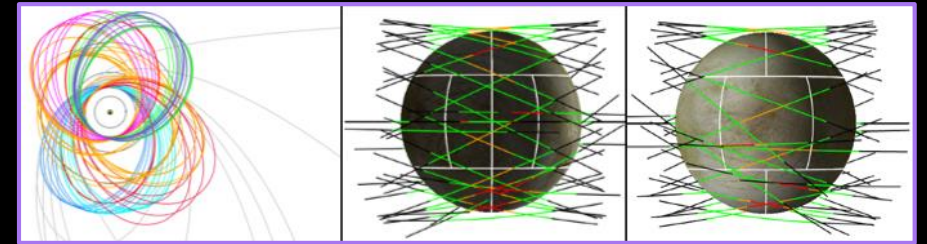


"Science and Reconnaissance from the Europa Clipper Mission Concept: Exploring Europa's Habitability" LPSC 2015

Strategy 1: Radiation-tolerant parts

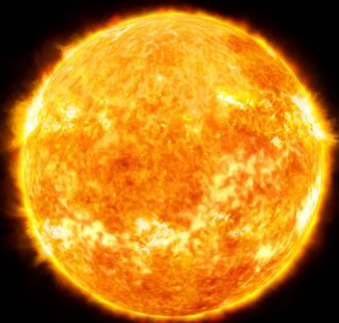
Strategy 2: Vault (shields electronics)

Strategy 3: Flyby trajectory design





Challenge: Thermal Extremes & Multiple LVs



0.65 AU

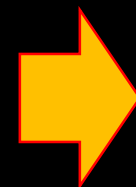


1.0 AU

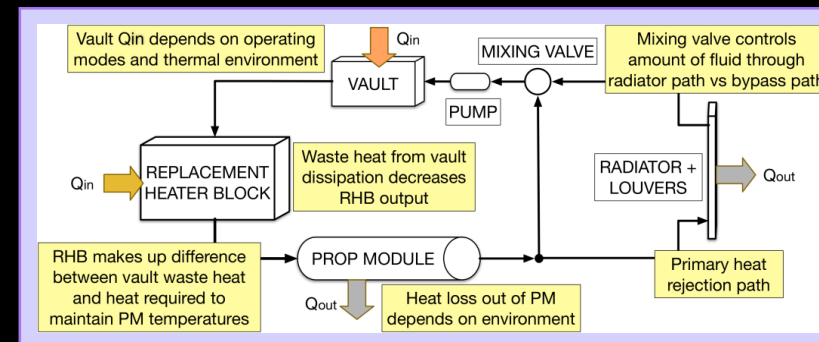
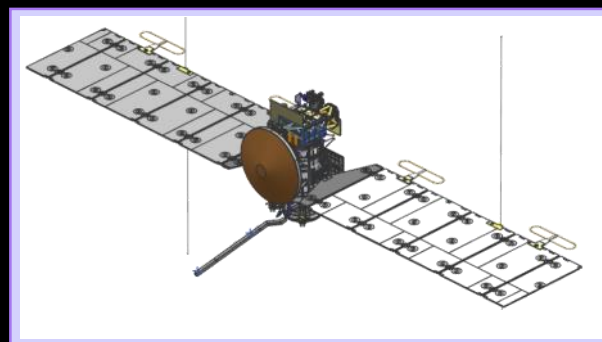


5.6 AU

- Hot: possible inner cruise
- Cold: Jupiter + 9-hour Eclipse
- Solar mission
- Multiple LV = Different dynamic, shock, and acoustic environments



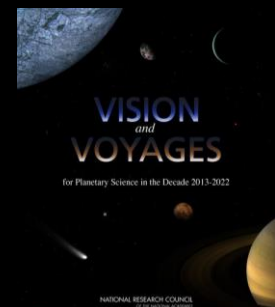
- Design for enveloping worst case (plus margin)
- Optimized Thermal Architecture
 - Reuse waste electronics heat
 - Pumped fluid loop transports waste heat
 - Radiator and sun shade for possible inner cruise



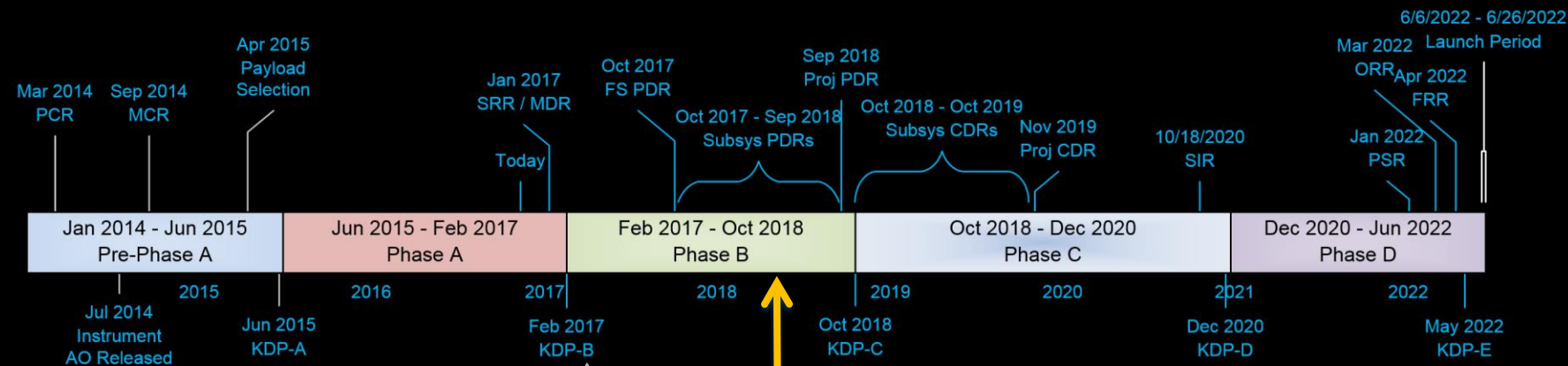
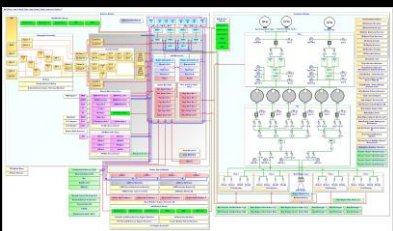
SLS Block 1B | SLS Block 1 | Delta IV Heavy



Where are we now

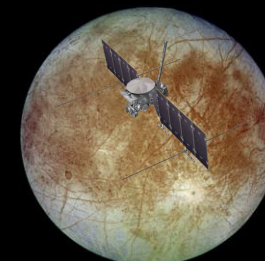
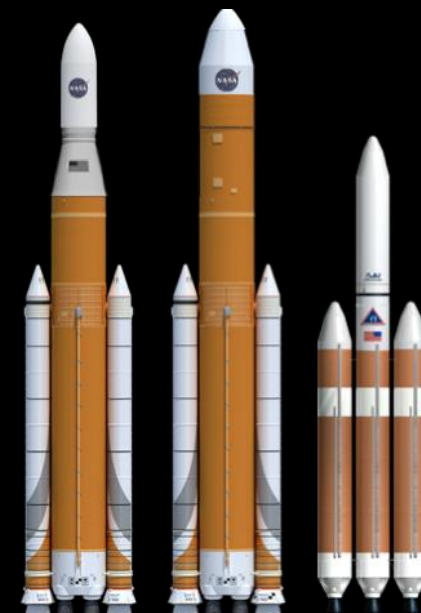
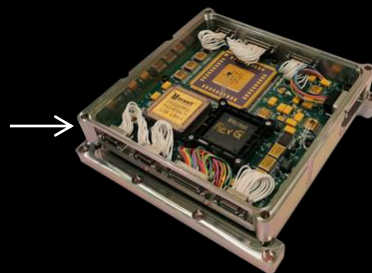
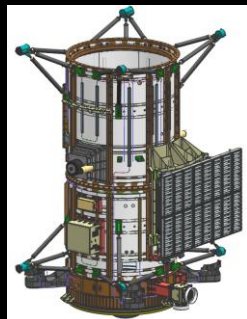


Decadal survey



(Last Update)

We are here

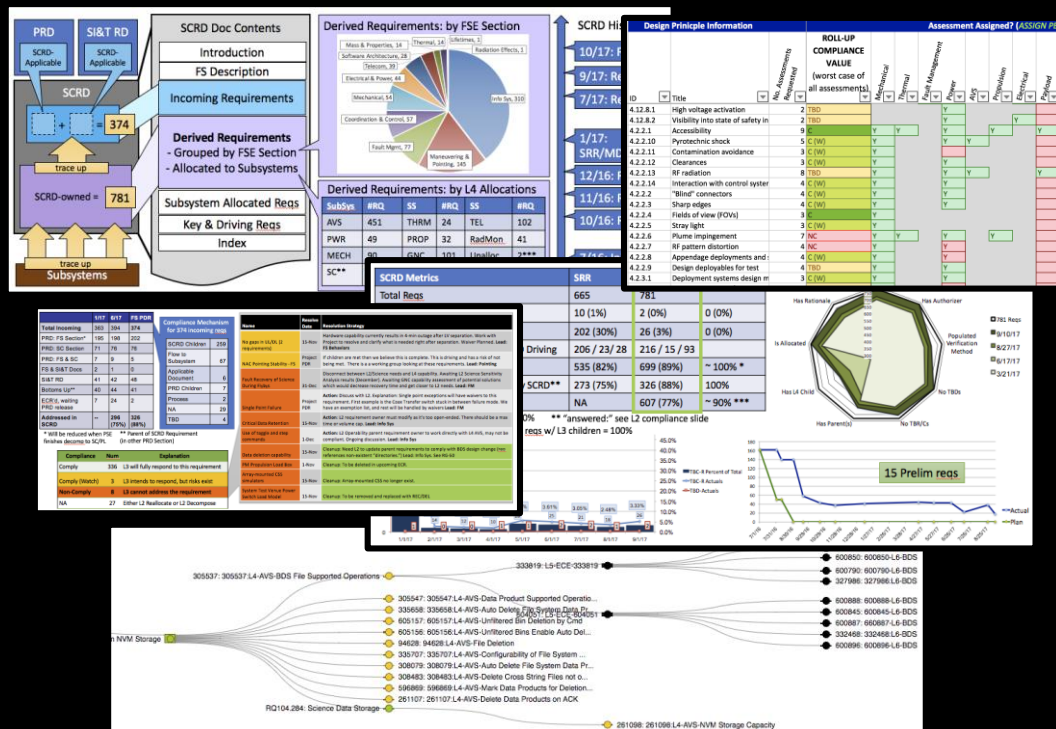




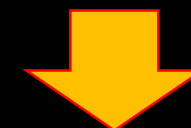
Evolving Systems Engineering Focus



Focus: 2017 → Project PDR



- Requirements Development
 - L2 → L3 → L4; Quality & Completeness
 - Traceability assessments
 - Finalizing requirements
 - L2 / L3 Requirements flow solidified
- Change Control processes established
- FS and Subsystem Reviews (PDRs)
- Functional Design Documents (FDDs) Initial Release



- Project PDR
- Verification & Validation development
- L3 / L4 Requirements flow finalization
- FMECAs
- Command and Telemetry Dictionaries
- etc

Requirements Development: metrics, issue tracking, traceability, burndowns



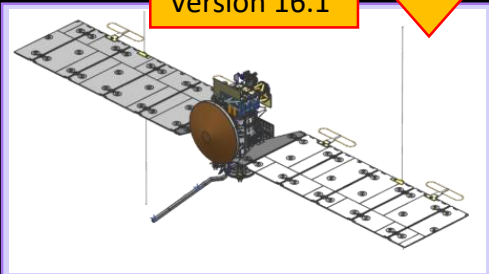
Selected FS Updates



Version 14.2



Version 16.1

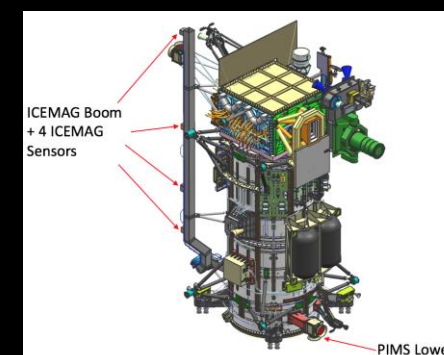
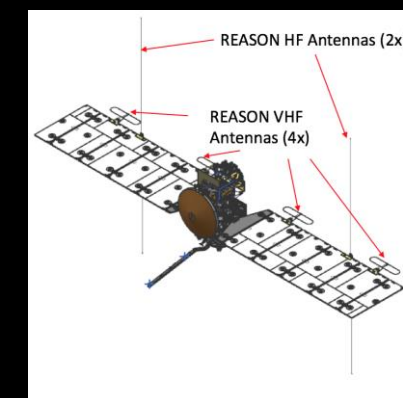
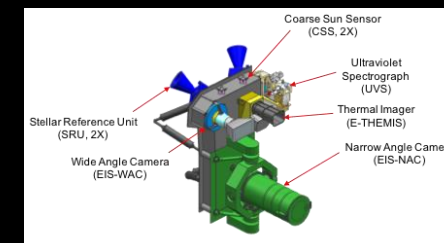
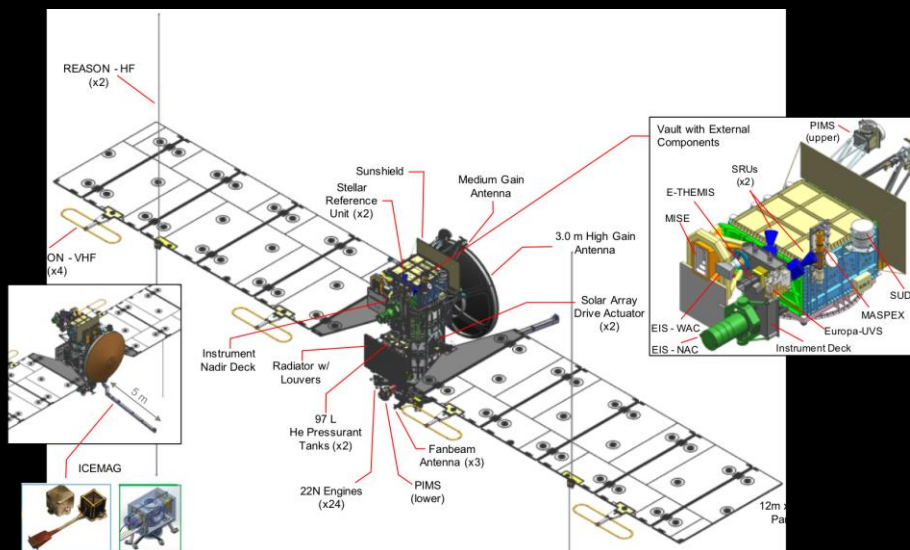


- 2300 kg FS Dry mass
- Payload Mass (Alloc): 310 kg
- 348 Ah Battery
- 90 m² Solar Array area
- 5.5 TB Downlink capability

- 2550 kg FS Dry mass
- Payload Mass (Alloc): 380 kg
- 348 Ah Battery
- 86 m² Solar Array area
- 5.1 TB Downlink capability

- Propellant Tank Size Selected
- SSIRU baselined as IMU
- ICEMAG boom single hinge deployment
- PME, Prop Module and Prop Subsystem PDRs
- BDS architecture baselined
- LSA/LVA baselined
- Array size baselined

- HRS pump speed increased
- Moved RF electronics out of Vault to "RF mini-vault" on Prop Module
- REASON VHF dielectric-less design
- MISE single Dyson cryo-cooler and radiator
- PIMS electronics moved out of vault, sensor added baffle
- REASON VHF spacing, HF position



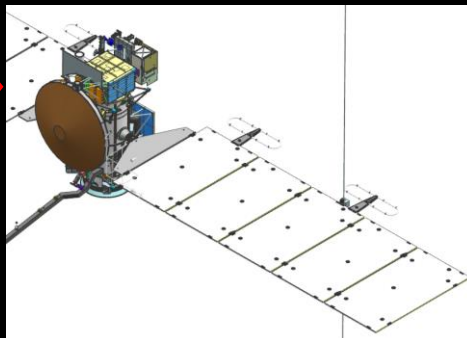
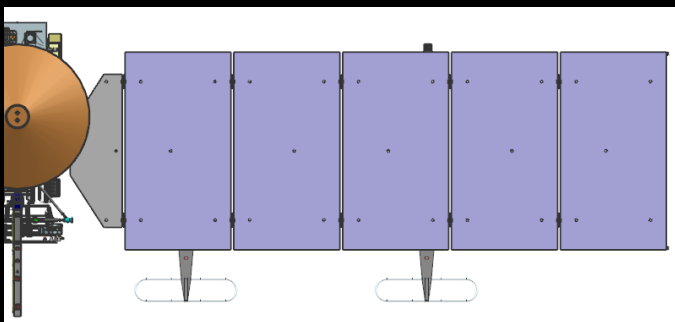
- REASON: HF/VHF Antenna move & spacing
- PIMS: electronics relocation (vault → sensor heads)
- EIS: inductosyn descope; addition of launch locks
- SC-Instrument Interfaces (electrical, thermal, power)
- Instrument ICDs (Interface Control)
- Instrument FDDs (Behavior)



REASON / Solar Array Integration



SRR/MDR (Jan 2017) Baseline ("A5")

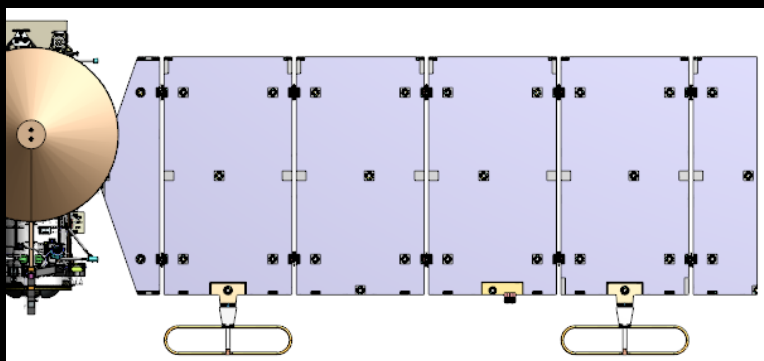


What: HF antenna moved to same side as VHF antenna
Why: Reduced complexity/mass of launch restraint architecture

New issues: unacceptable stresses on SA; need to reduce SA mass and inertia

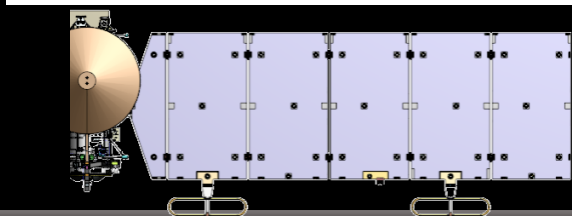
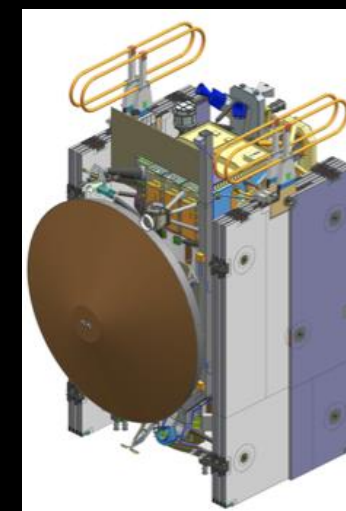


FS PDR (Oct 2017) Baseline ("A7")



- What: HF and VHF antenna spacing updated (VHF must be in center of panel; HF near center of panel)
- What: SA 5 panel → 4.5 panel
- Analysis: science, stresses, keep-out-zones

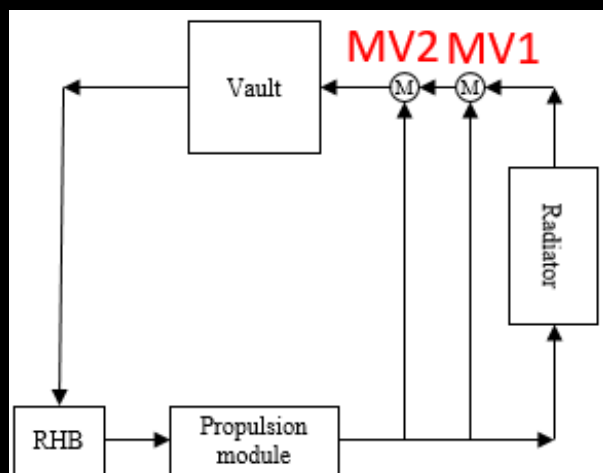
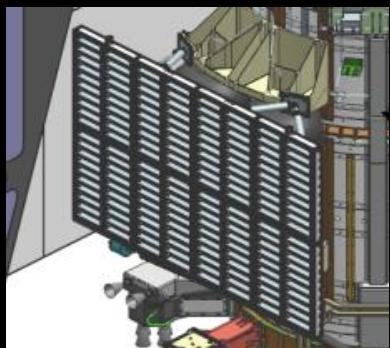
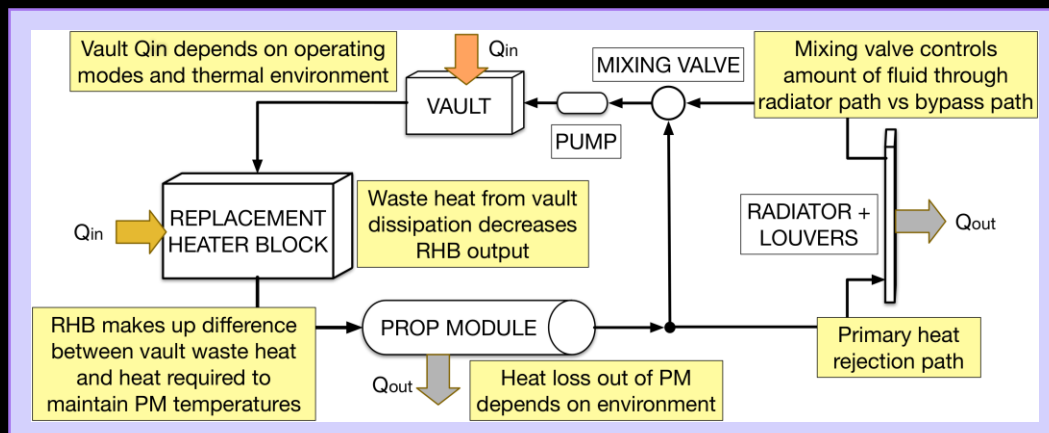
- Further work on interface properties:
 - cabling on SA
 - Solar array edge ground feature
 - Conductivity/resistance constraints
 - Loads, mass, other dynamics



5-Panel Solar Array
Compatibility
Cells on Yoke



Thermal Design Trades and Updates



- Increased fluid flow rate (0.75 LPM \rightarrow 1.5 LPM)
 - Problem: Prop Module was too hot
 - Option: change design of mixing valve
 - Option: change pump impeller design to get 1.5 LPM
- Added radiator louvers
 - Problem: heat leak through radiator circuit in cold cases
 - Added louvers
- Added second mixing valve (in series)
 - Problem: heat leak through radiator circuit in cold cases
 - Second mixing valve reduces minimum flow through radiator from 4% to $< 0.3\%$

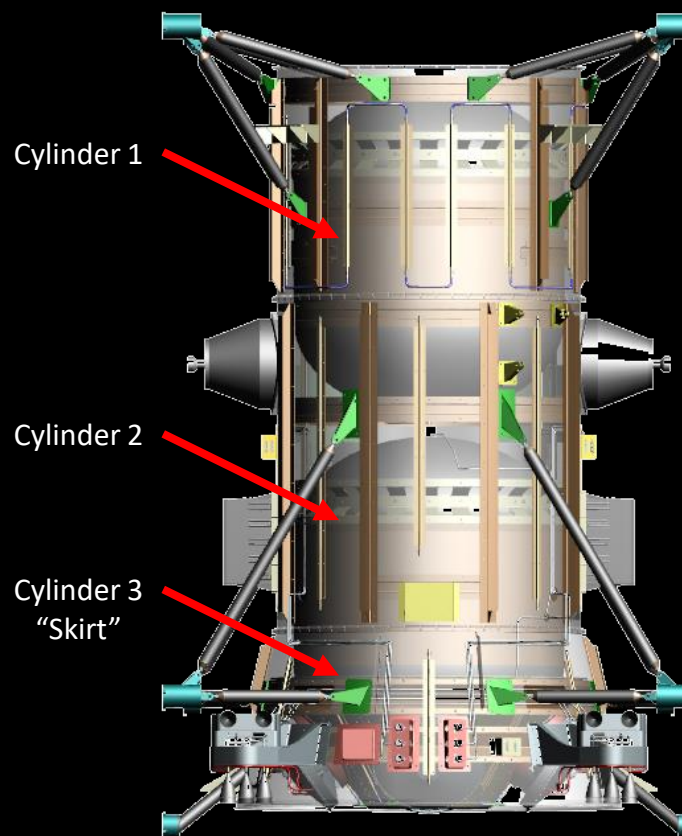


Propulsion Module Updates

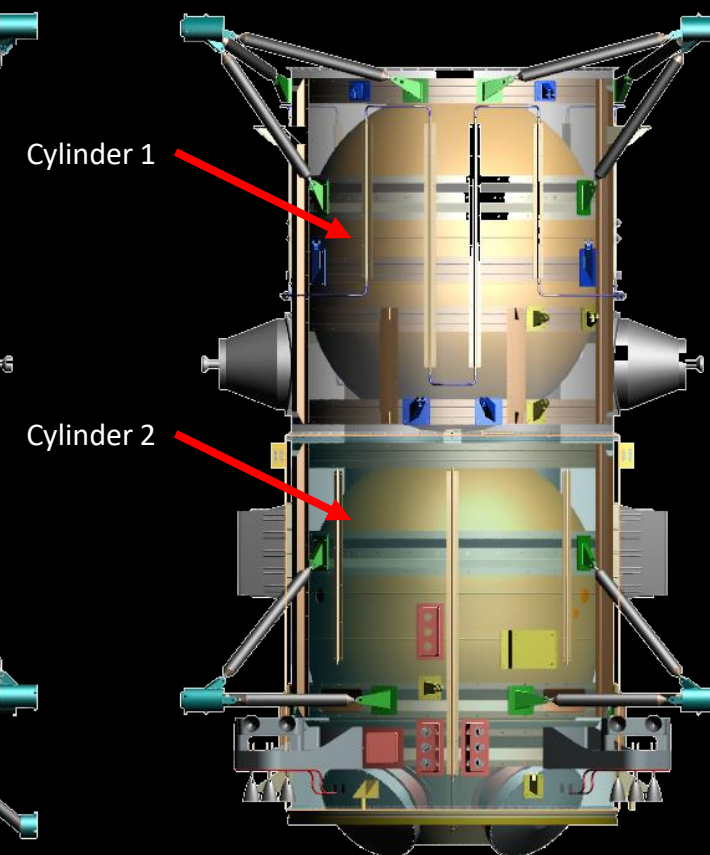


- Propulsion Tank Size

- A5 Configuration: 2450 kg propellant
 - Assumed SLS Block 1
 - Resulted in <20% mass margin required at Project PDR
 - Undersized for SLS Block 1B
- Update: 2750 kg propellant
 - Impact: larger diameter SC body
 - Adjustments to maintain FOVs for antennas, sensors (SC and Instrument)



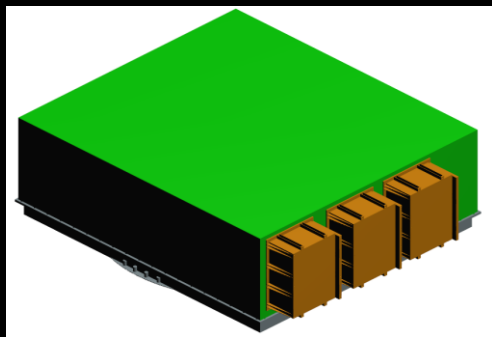
A5 Configuration



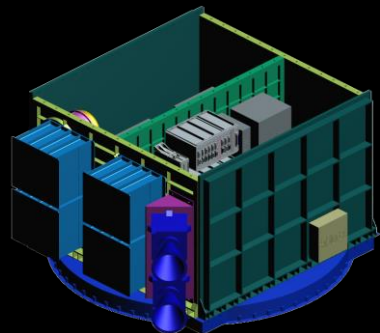
A6 Configuration



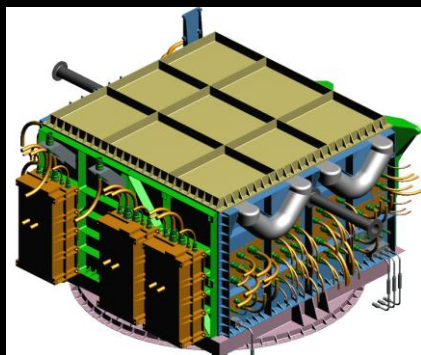
Vault Configuration



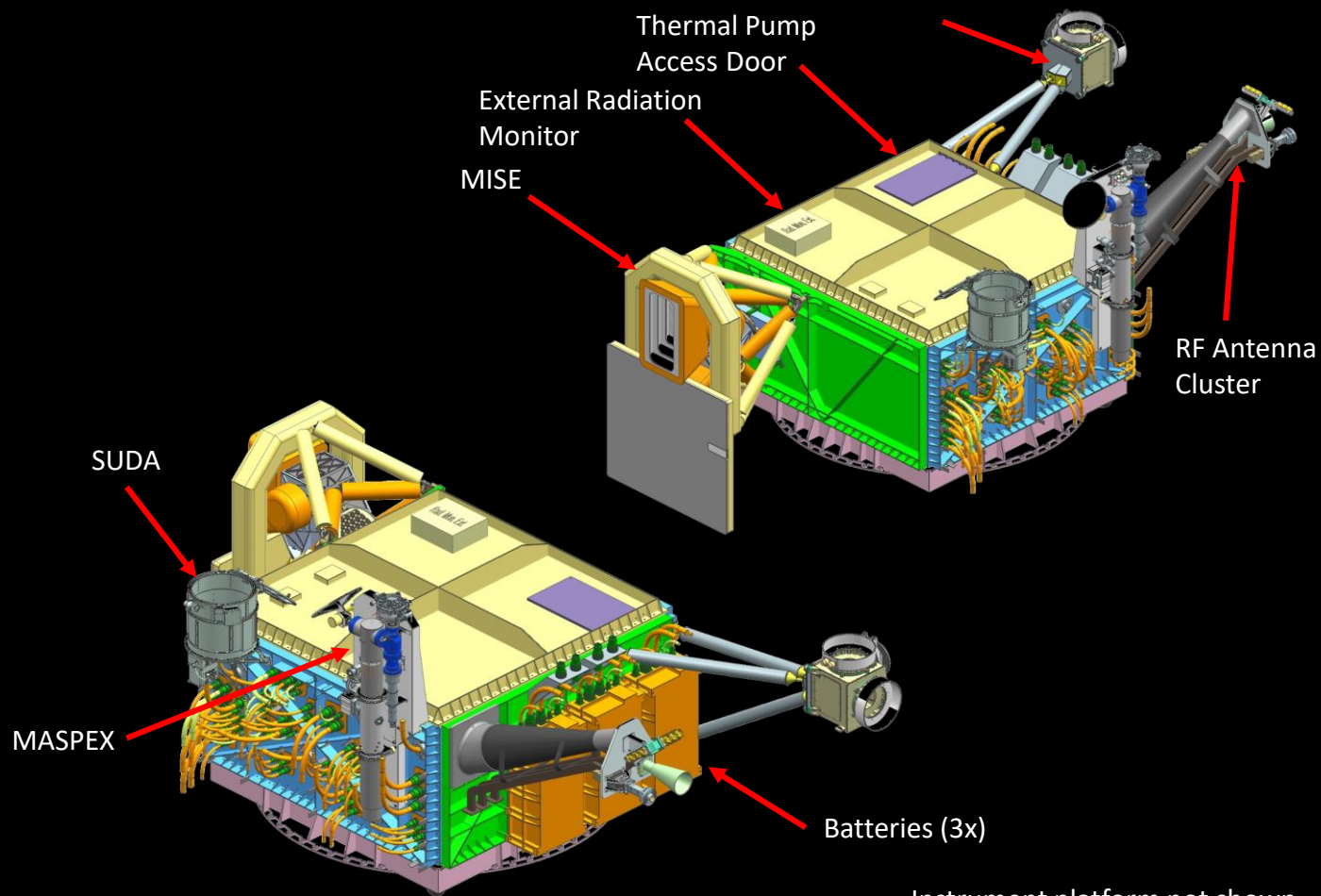
"Pancake" Vault



Center Panel Vault



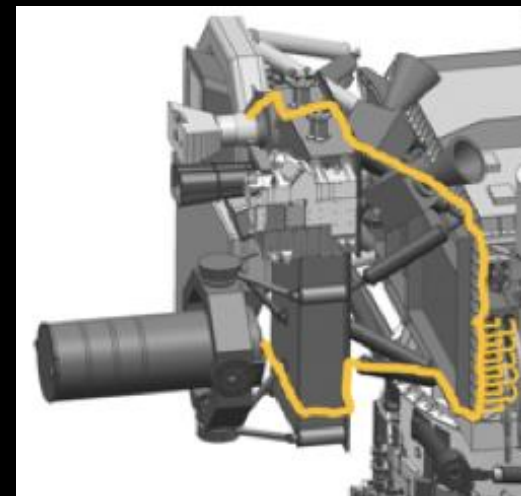
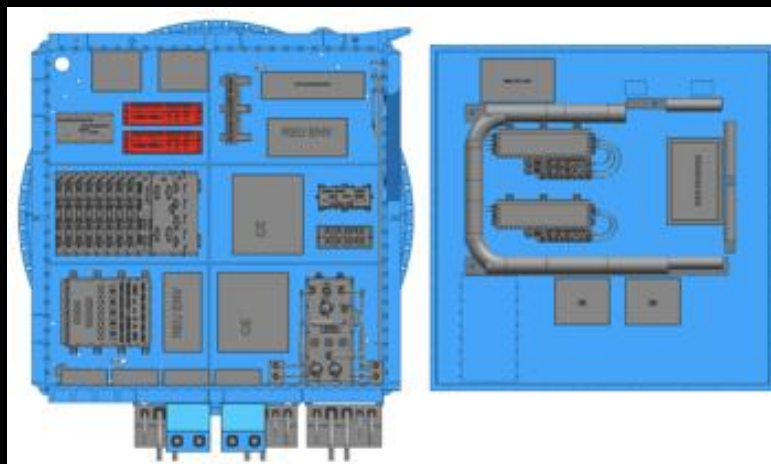
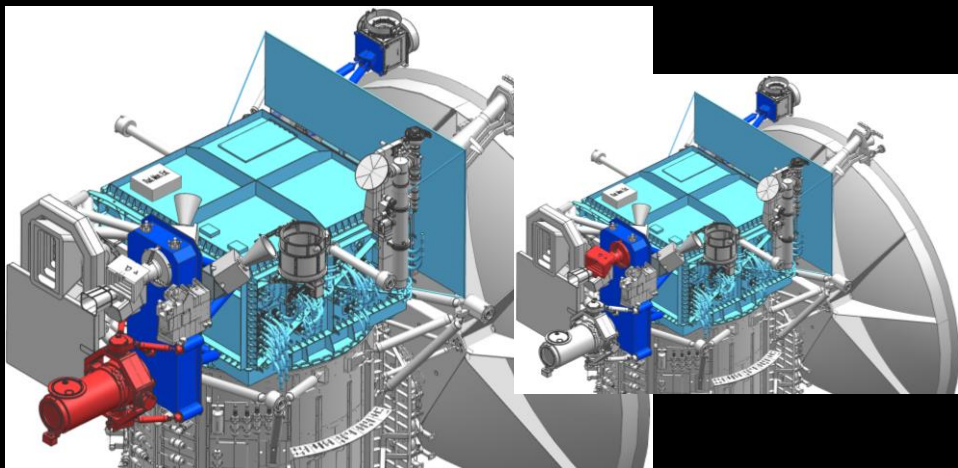
" \pm Z" Vault



Instrument platform not shown
Instrument covers shown open



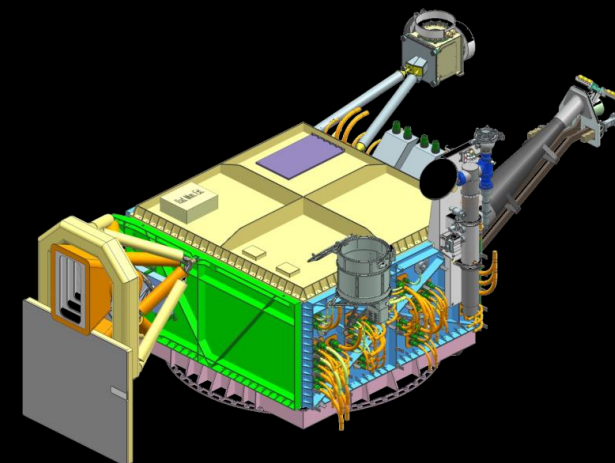
Instrument Accommodation Example



Cartoon sketch of possible cable routing

- EIS Accommodation (NAC, WAC)
 - Thermal Requirements (in and out of vault)
 - Power, electrical services, cable routing
 - Vault penetrations
 - Volume
 - FOV

Major focus: negotiating and baselining these interfaces





Future Work



Trades Completed (to be incorporated)

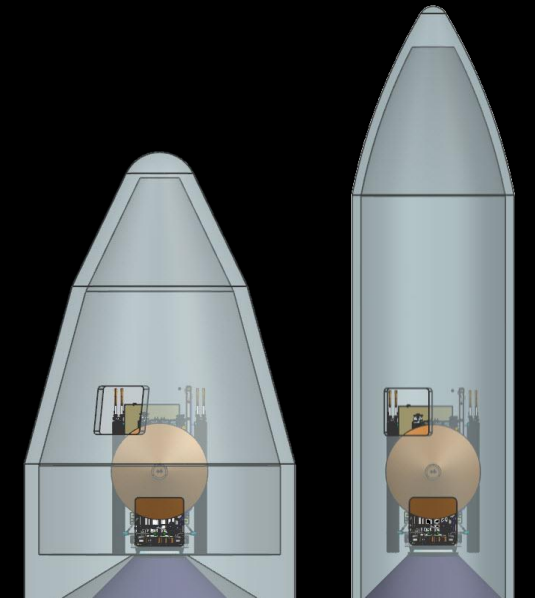
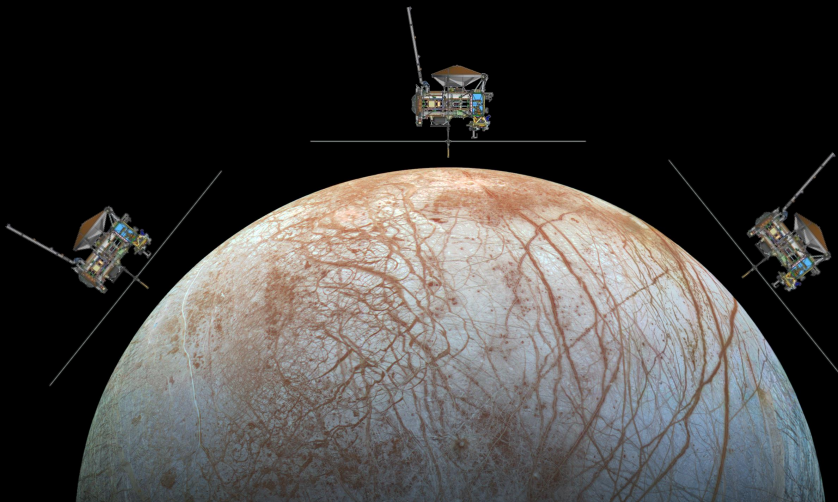
- CSS/DSS Trade
- CM Offset Trade
- ICEMAG Cold Survival Approach
- PME Undervoltage

Future Trades

- Reaction Wheel Trade
- Deployment Monitoring Approach
- SSIRU (1 vs. 2)
- PIMS Charging
- Electrical Isolation approach
- Unintended Delta-V Strategy
- REASON Antenna Accommodation
- TWTA Magnetic Interference
- JOI Assumptions and Timeline
- Deployment Initiation Approach for ICEMAG Boom
- Integrated Shipping Approach
- Thermal Roll during Launch
- ICEMAG Electronics Location
- Full Energy Analysis of Launch and JOI
- TLM Downlink during every Europa Flyby
- Radiation Robustness/Cost Trade
- Optical and Radiator FOV Operations Impact
- Quartz Crystal Microbalance

Requirements & V&V

- Requirements Releases for Project PDR
- V&V Approach Descriptions
- Requirements Gap List Burndown
- TBx Burndown

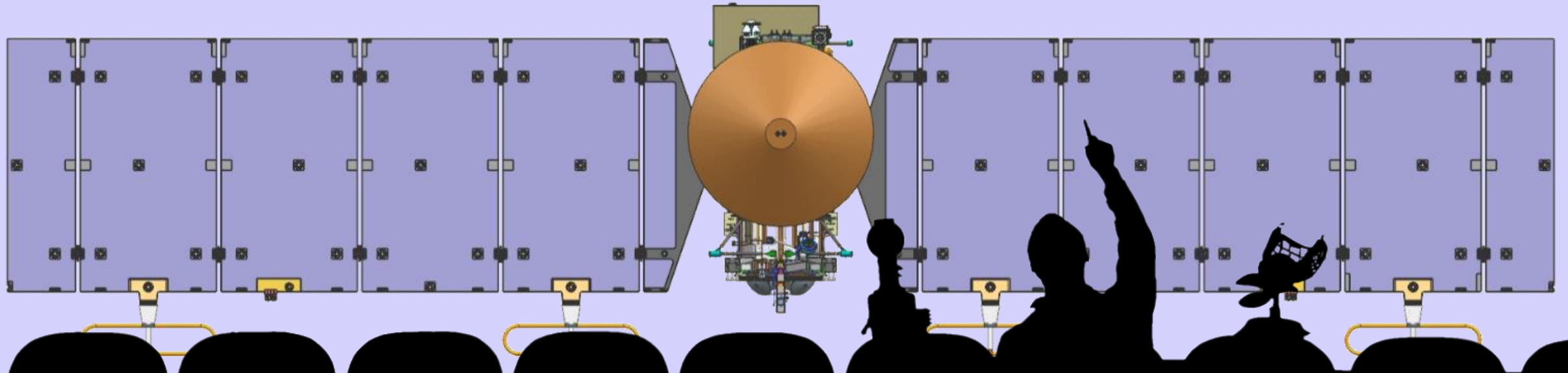


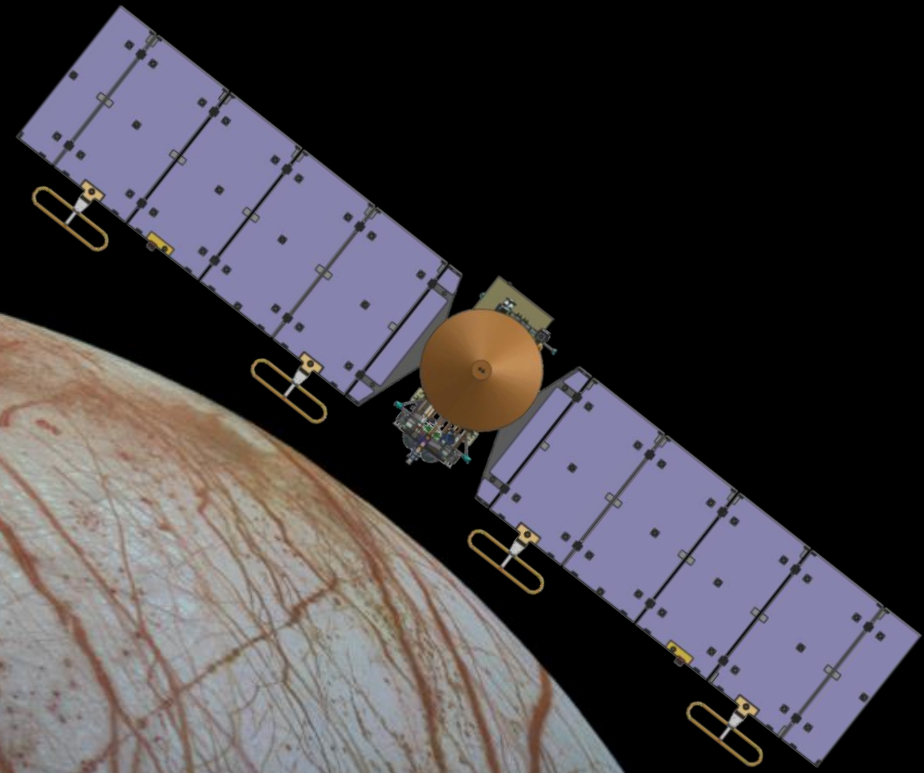
*SLS Block 1B
Fairing (option)*

*Delta IV Heavy
5m Fairing*



Questions?





Backup Material

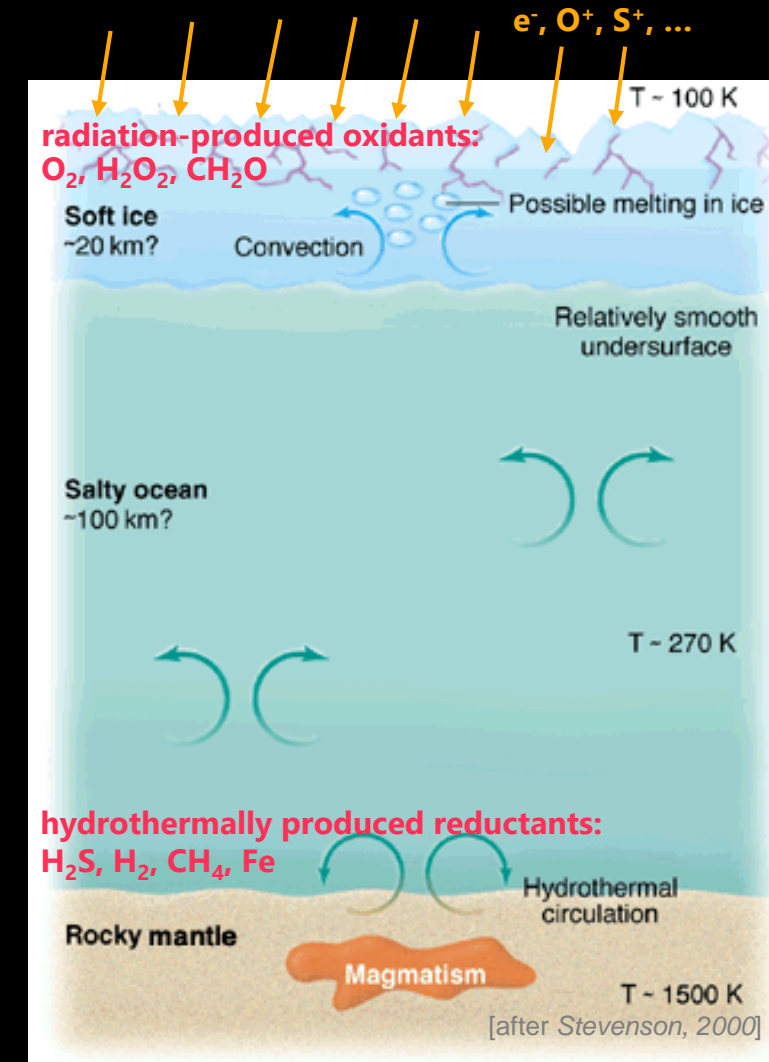
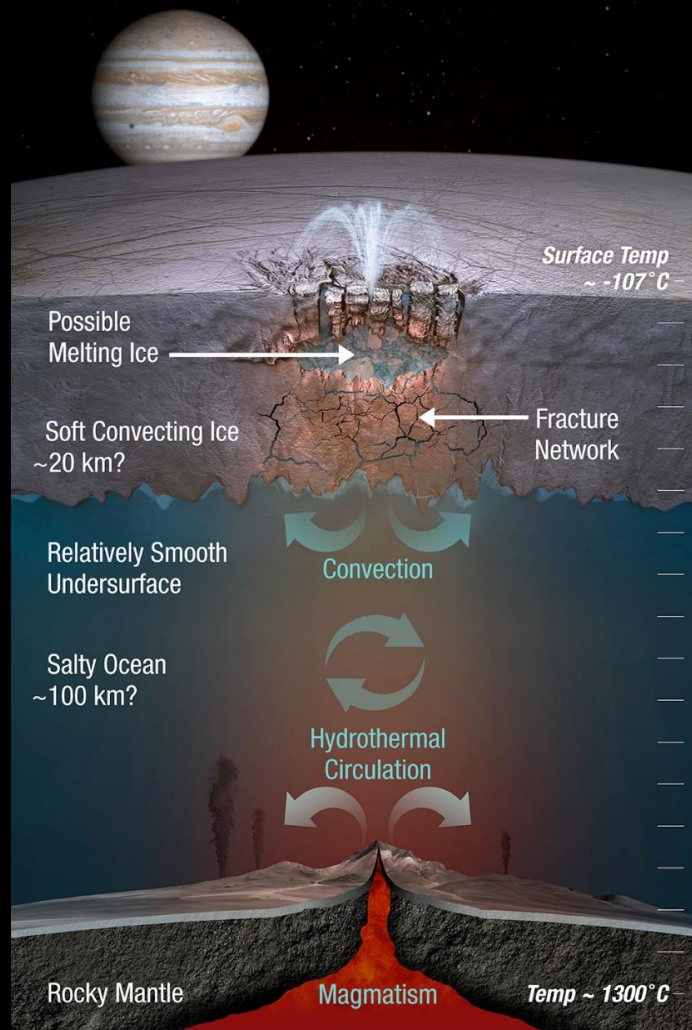


Europa: Ingredients for Life?



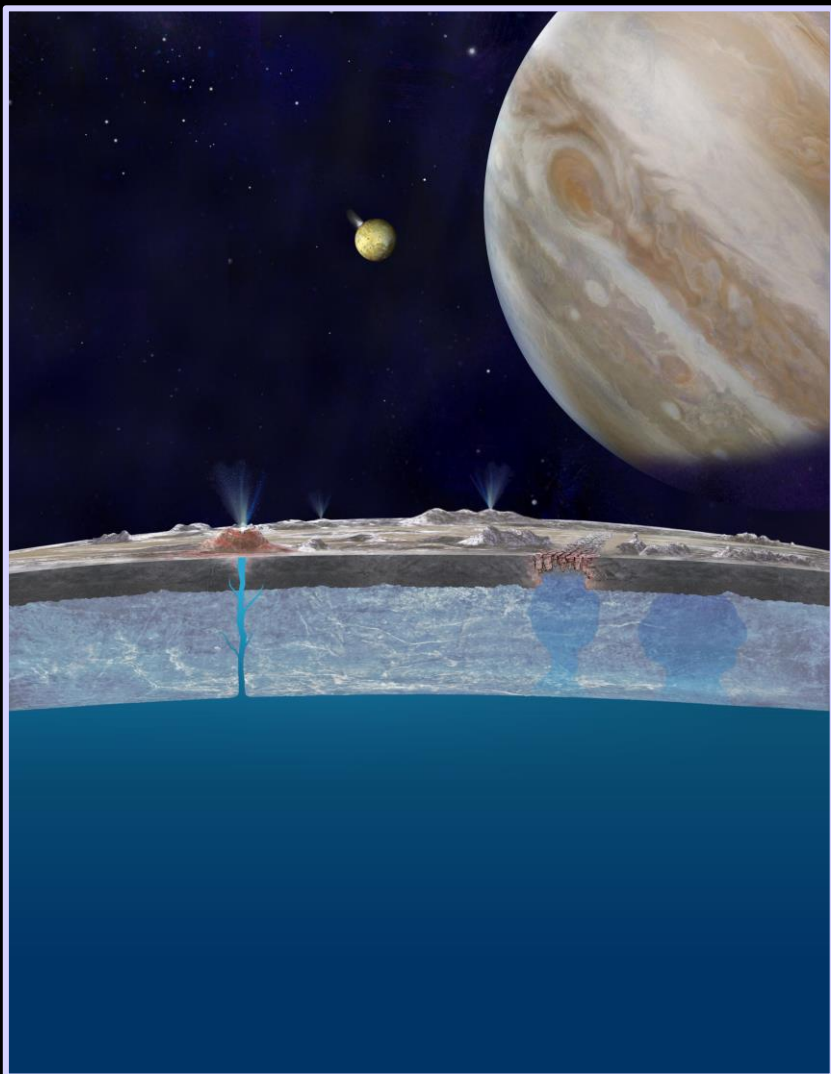
- Water:
 - Probable saltwater ocean, indicated by surface geology and magnetic field
 - Possible lakes within the ice shell, produced by local melting
- Chemistry:
 - Ocean in direct contact with mantle rock, promoting chemical leaching
 - Dark red surface materials contain salts, probably from the ocean
- Energy:
 - Chemical energy could sustain life
 - Surface irradiation creates oxidants
 - Mantle tidal heating could create reductants
 - Geological activity would “stir the pot”

The planned Europa mission would test habitability hypotheses

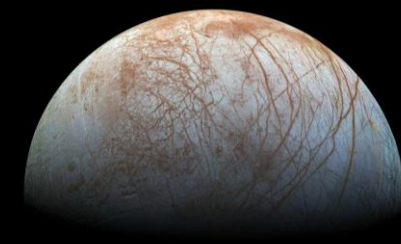
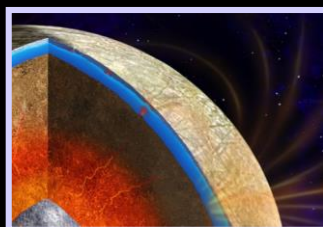




What are we looking at?



- In Situ investigations:
 - Detect and analyze composition of Europa's thin atmosphere
 - Detect and analyze particles originating on Europa's surface
 - Measure magnetic fields
 - Measure density, flow, and energy of ions and electrons
- Remote Sensing investigations
 - Look below the surface (*ice shell and ocean sounding*)
 - Image the surface
 - Locate and characterize plumes
 - Analyze composition of surface (*organics, acid hydrates, salts*)
 - Search for thermal anomalies (*plumes, venting, resurfacing*)
 - Assess possible landing sites (*for potential future mission*)

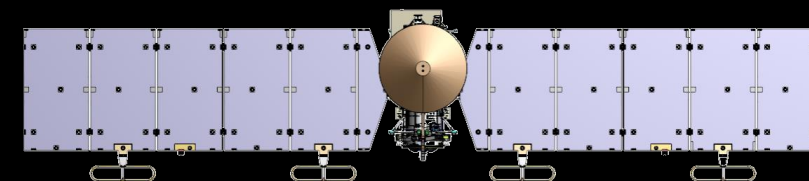
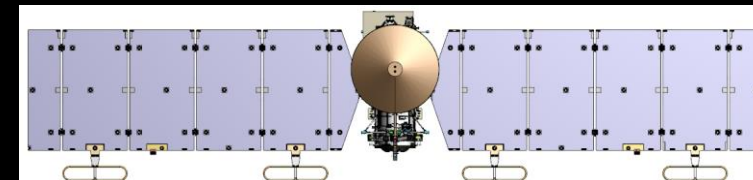
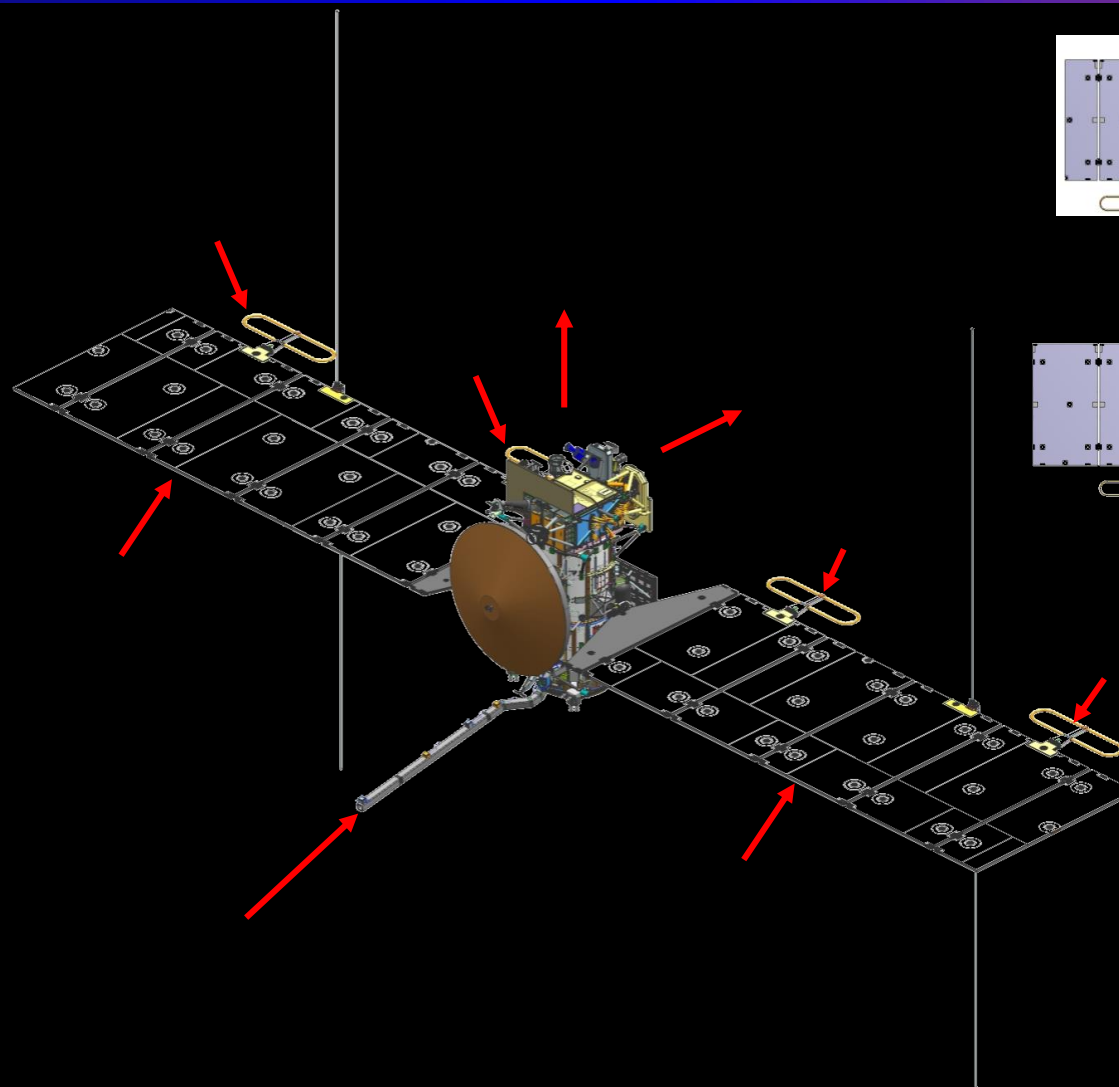




Deployed Configuration - Overview



- Single axis gimbal (1 per SA wing)
- Passively deployed SA wings
 - spring/damper with synchronization system
- Cells face direction of HGA (-Y) for power generation and telecom
- Reason Antenna SA edge fixed on Nadir (+Y) direction for closest portion of Flyby

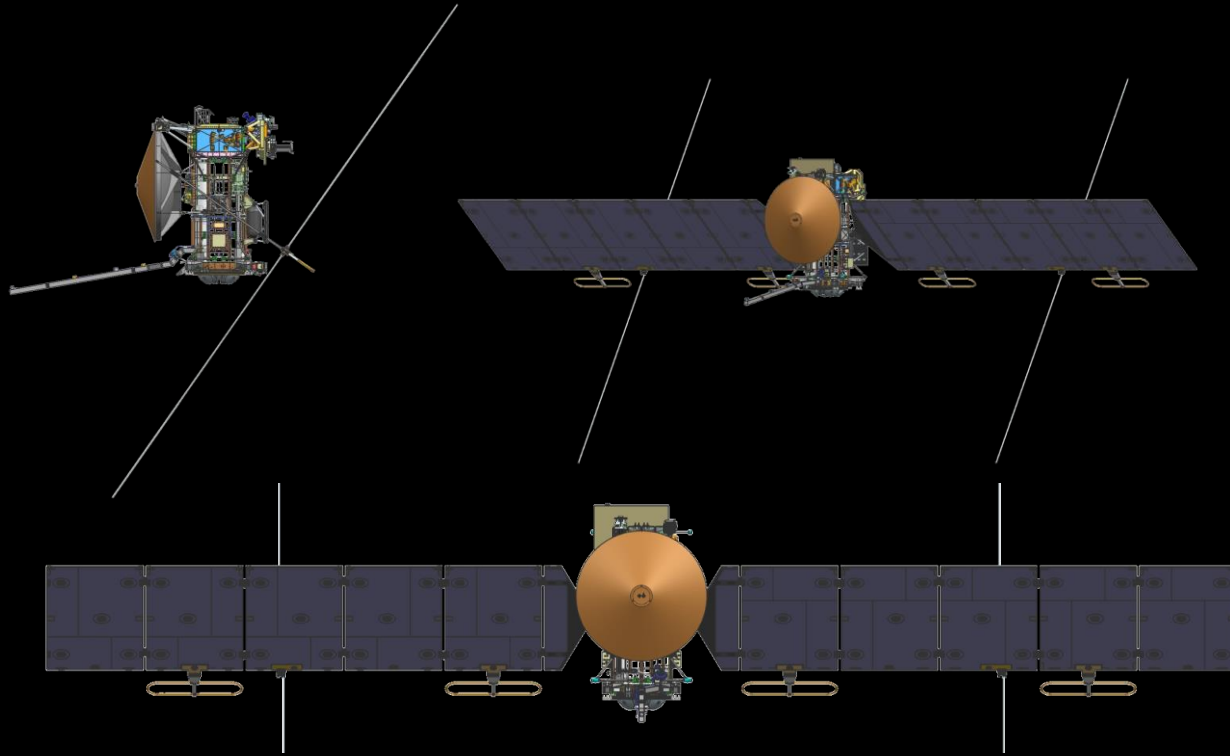




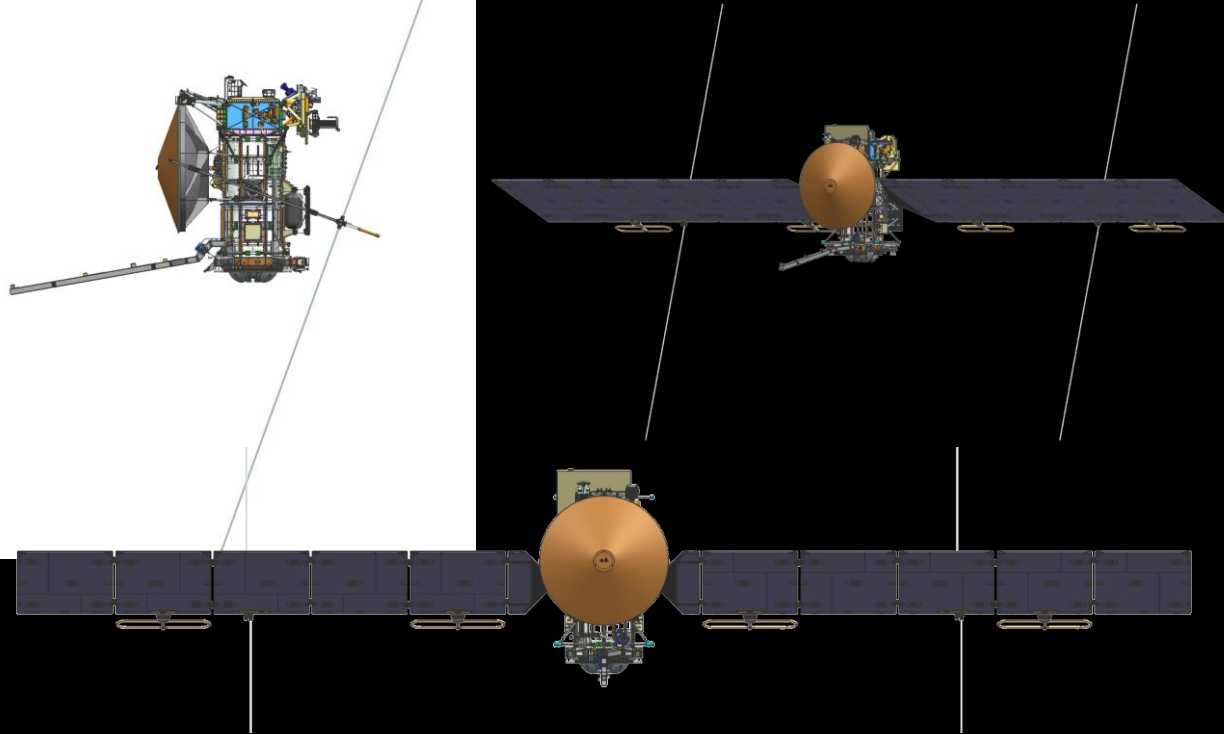
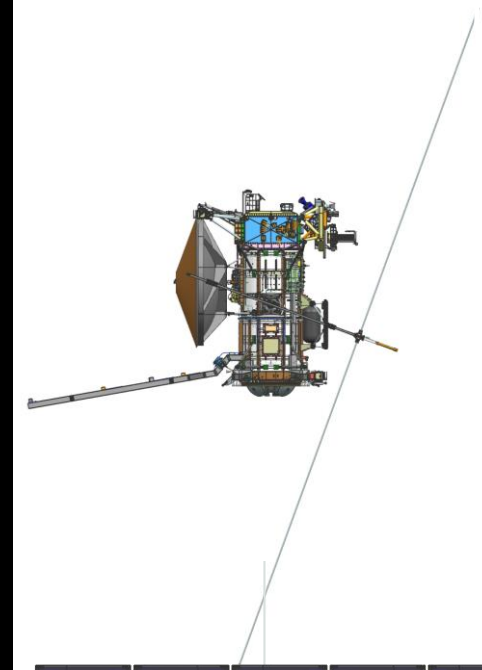
Deployed Configurations – Venus Gravity Assist



Deployed – Venus Solar Array Angle: 55°



Deployed – Venus Solar Array Angle: 70°



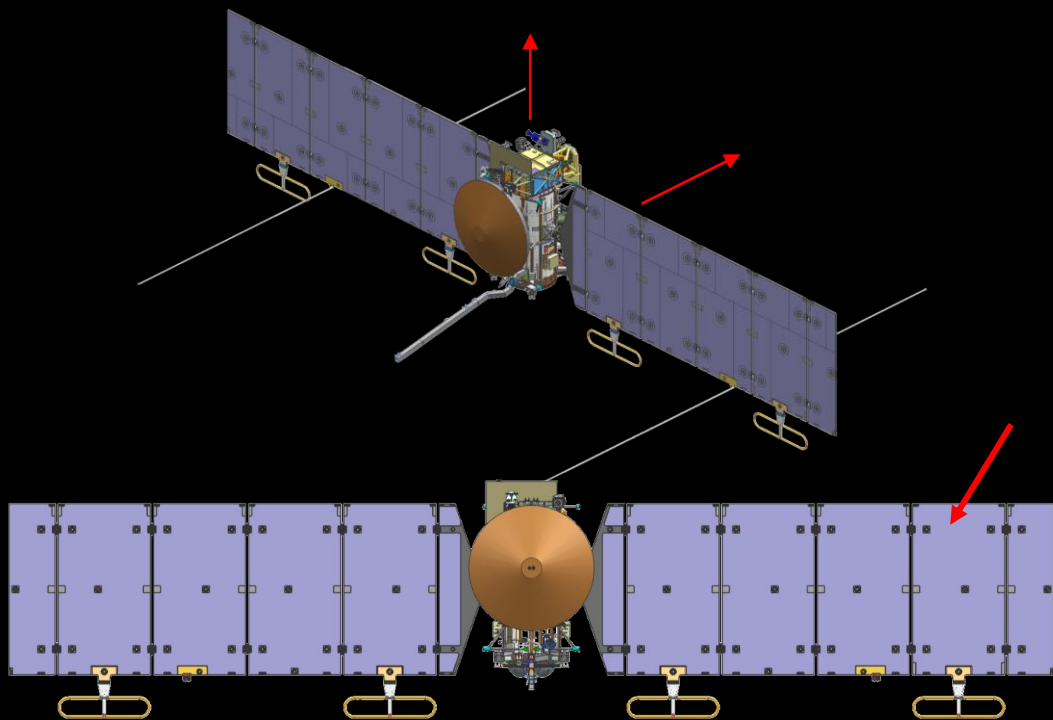


Power and Flyby Configurations



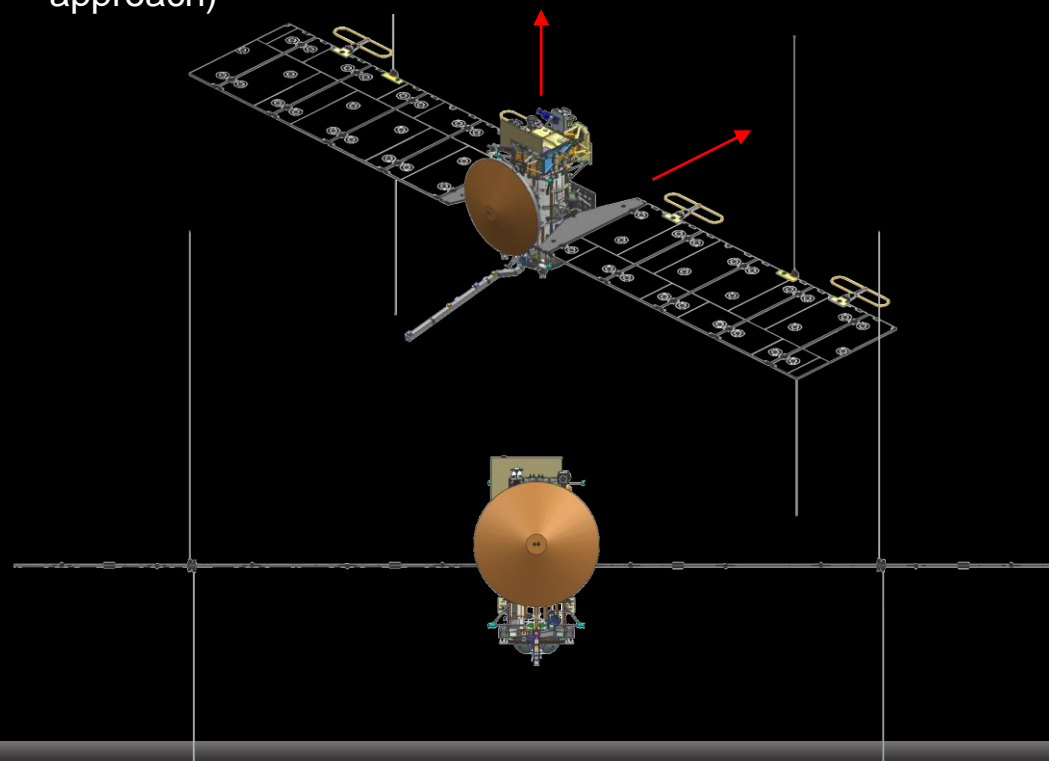
Power

- Nominal power generating / telecom configuration during cruise and during the science tour, outside of the flyby
- HGA pointed to Earth, SAs pointed to Sun, maximum SPE angle: up to 11°
- Instruments shaded by Vault mounted Sun Shade



Flyby

- Used during flyby of Europa (roughly $\pm 1,000$ Km of closest approach) for REASON science
- Solar Arrays fixed during this period for stability and REASON science
- Solar Arrays articulate during science tour outside of closest approach)

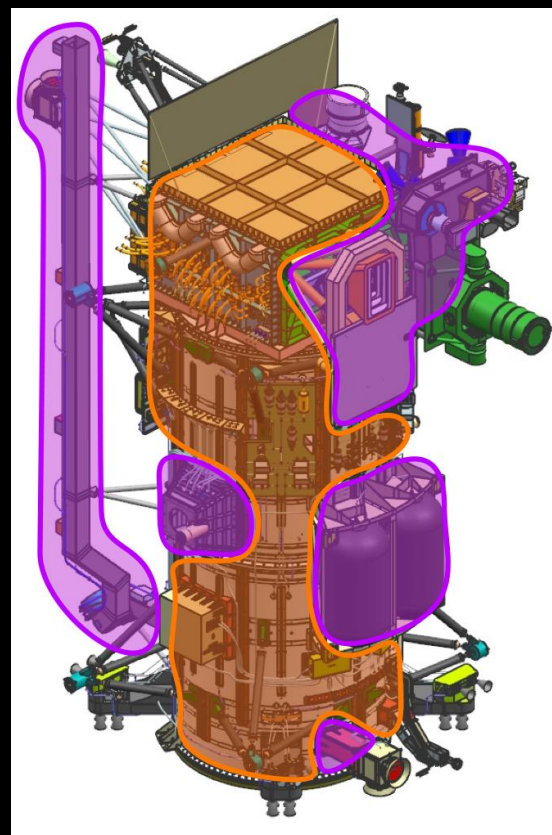




Thermal System Architecture



- Thermal Challenge: minimize energy usage at Jupiter; survive hot inner cruise
- HRS (orange)
 - “R” = rejection, reclamation, reuse
 - Reuse dissipation heat from vault to heat Prop components
 - Pumped fluid loop + replacement heater block
 - Thermal Radiator
 - Covers majority SC components
- Active thermal control (purple)
 - For non-loop elements
 - Instrument interfaces (majority)
 - Some propulsion components
 - Sun sensors, solar array deployment components, radiator, etc
- Passive control (blankets, coatings, etc)



Concept: thermally isolated zones controlled with traditional closed-loop or thermostat heater circuits

Not shown:

- Solar Array Hardware
- Thermal Radiator
- REASON (on SA)

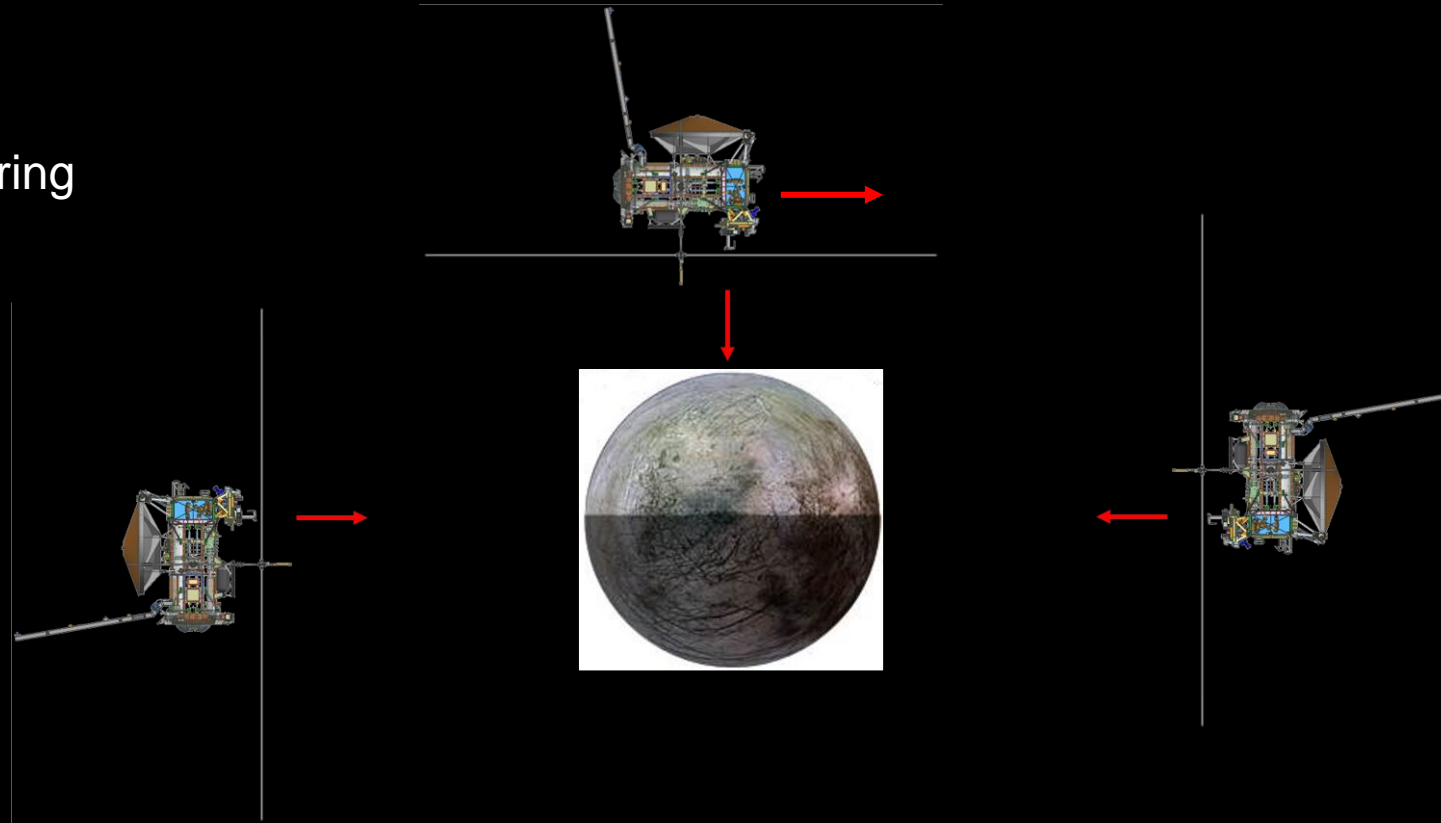
This is a cartoon sketch to illustrate the HRS/active concept



Europa Flyby Attitude



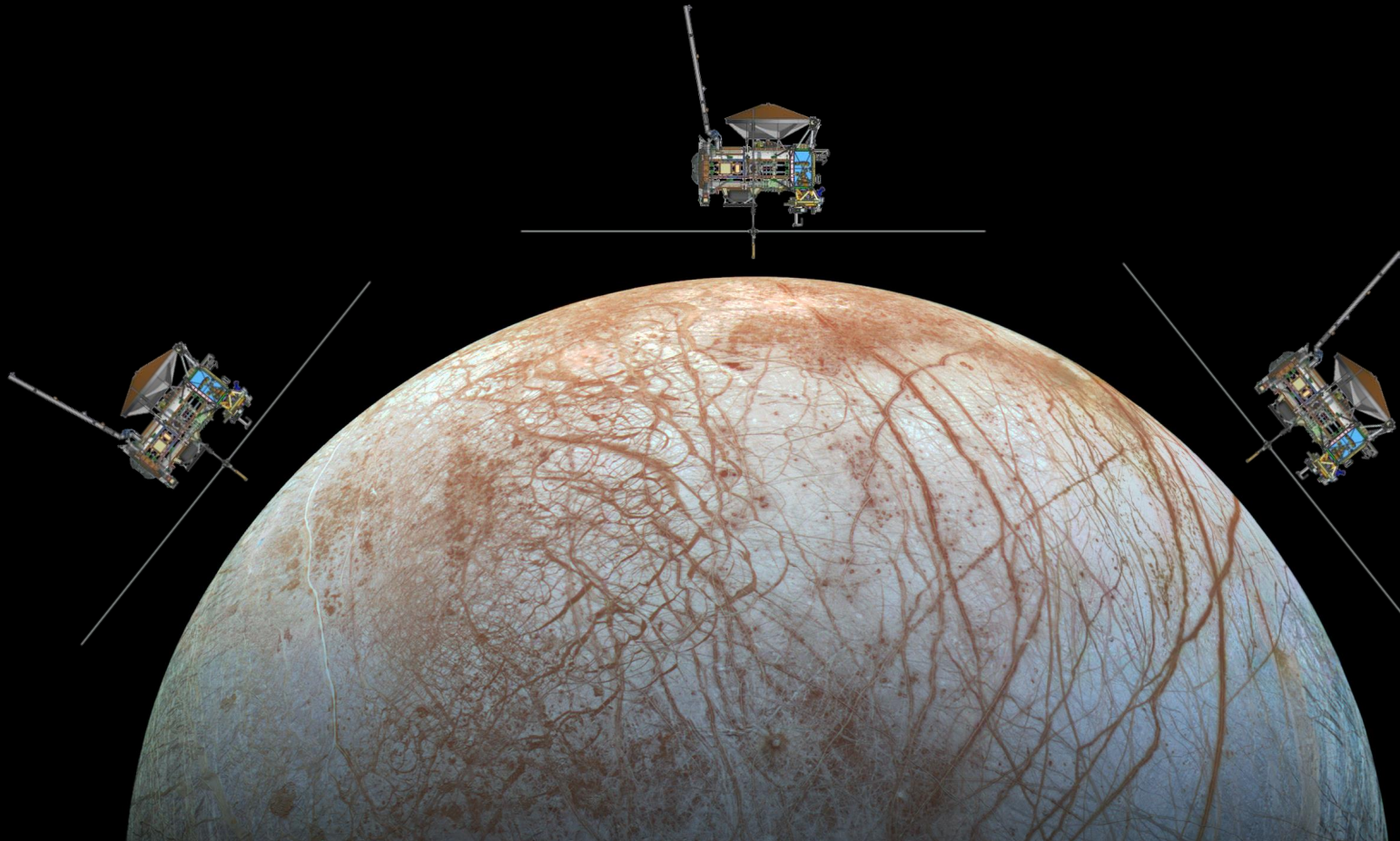
- Flyby
 - Nadir Pointing
 - Solar Arrays fixed in Flyby configuration during REASON science
 - In-Situ Ram instruments measuring during closest approach
- Petal
 - After Flyby ~ 1 – 2 weeks
 - Charge batteries
 - Data transmission
 - Prepare for next flyby
 - 40+ flybys



The technical data in this document is controlled under the U.S. Export Regulations; release to foreign persons may require an export authorization. Pre-Decisional Information
– For Planning and Discussion Purposes Only

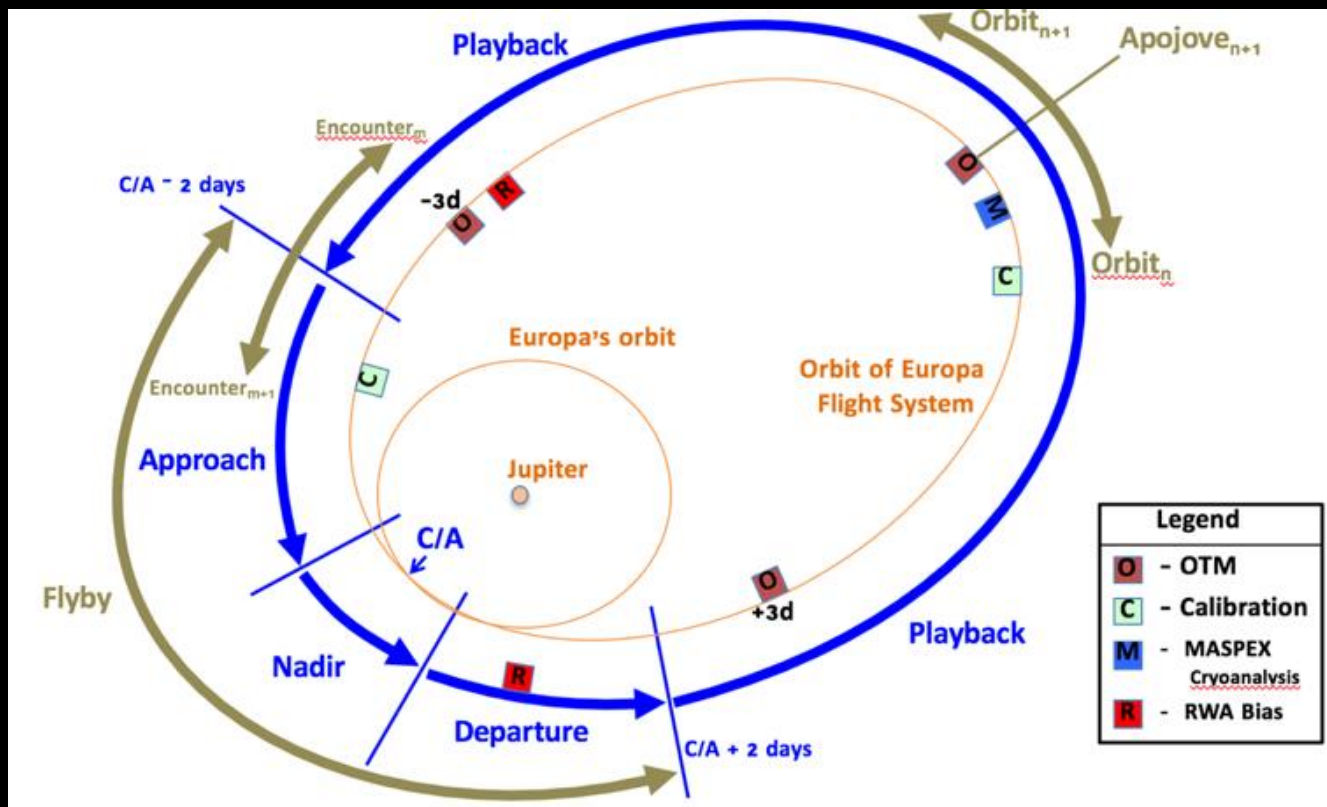


Challenge: Radiation Flyby and Orbit





Phases of an Encounter





Operating Modes During Mission Timeline

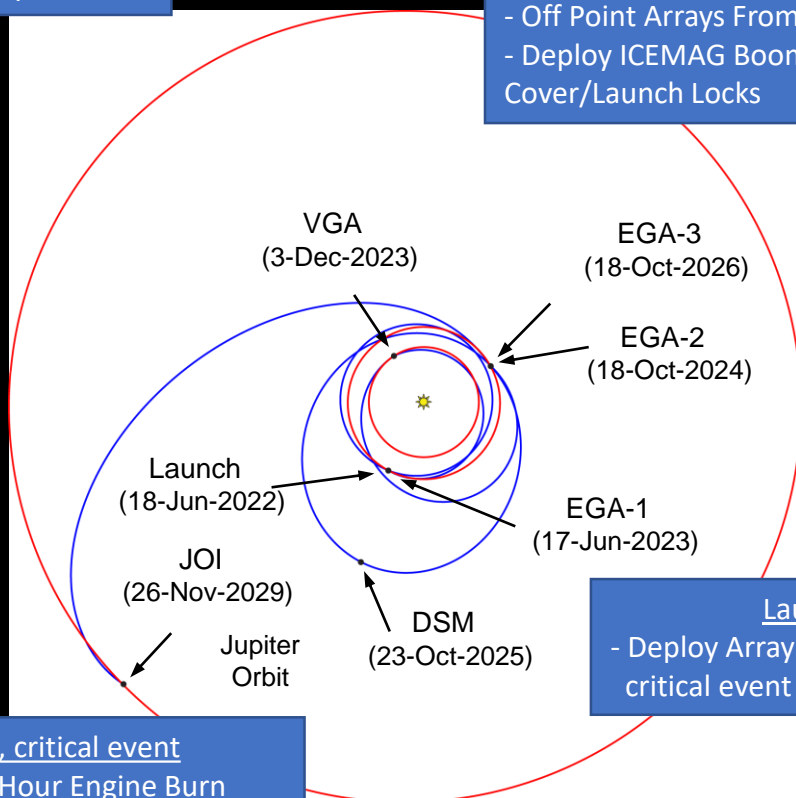


Outer Cruise

- Instrument Calibrations
- TCMs, RCS Control
- Sun Point Arrays

Inner Cruise (Option)

- Sun Point HGA
- Thermally Limited Off Sun Activities
- Off Point Arrays From Sun
- Deploy ICEMAG Boom, Instrument Cover/Launch Locks



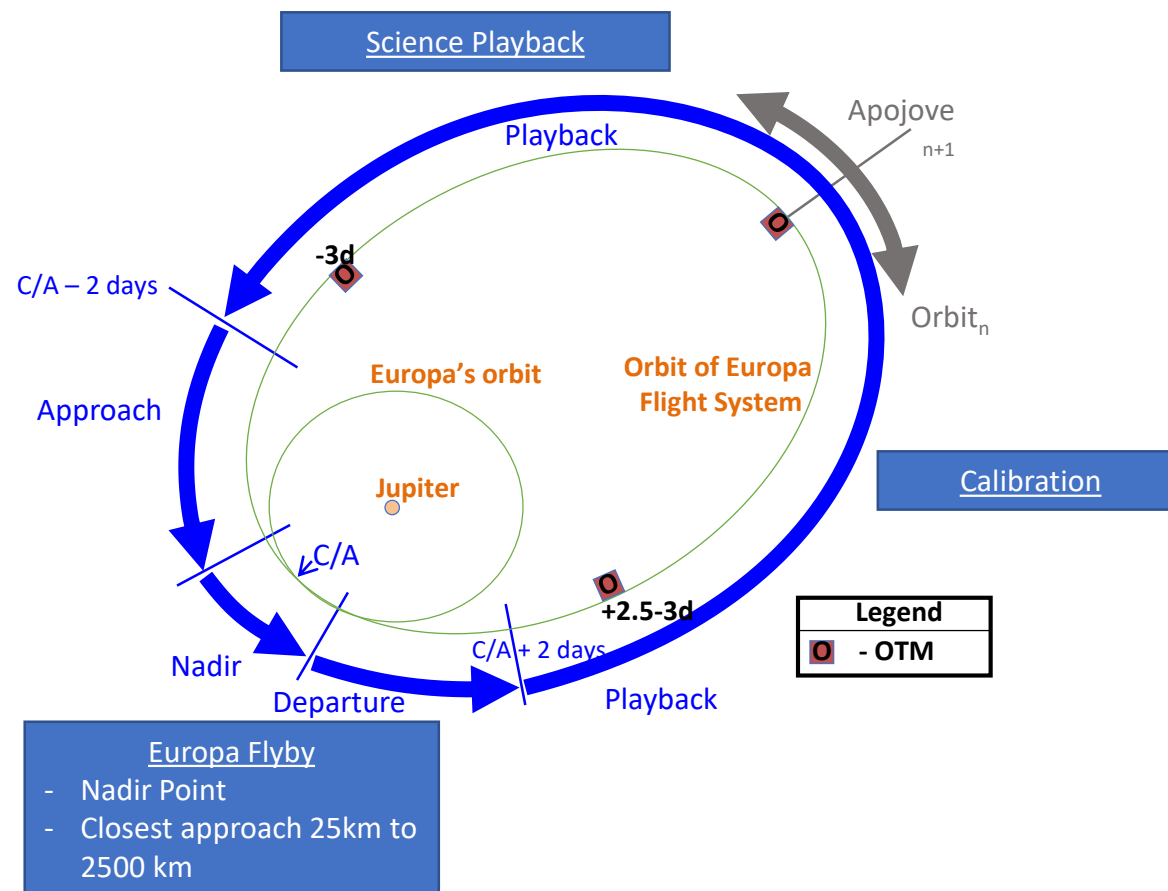
Launch

- Deploy Array: Sun Point, critical event

JOI, critical event

- 5.5 – 6.5 Hour Engine Burn

Encounter Period 10-14 Days



Europa Flyby

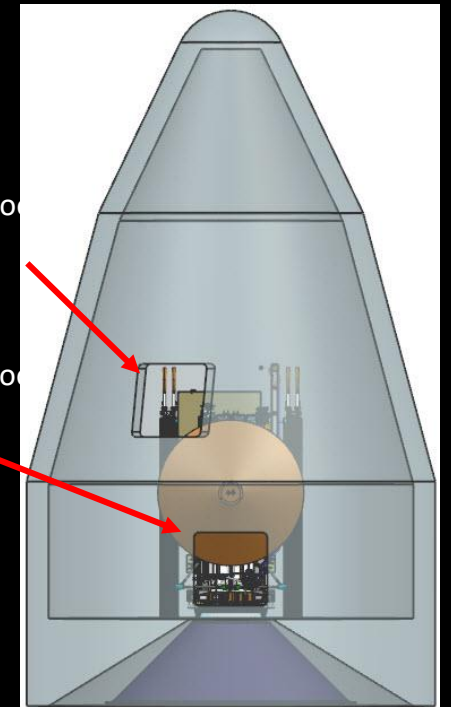
- Nadir Point
- Closest approach 25km to 2500 km



Delta IV Heavy
5m Fairing

Upper Fairing Access Door
Enable Plugs access

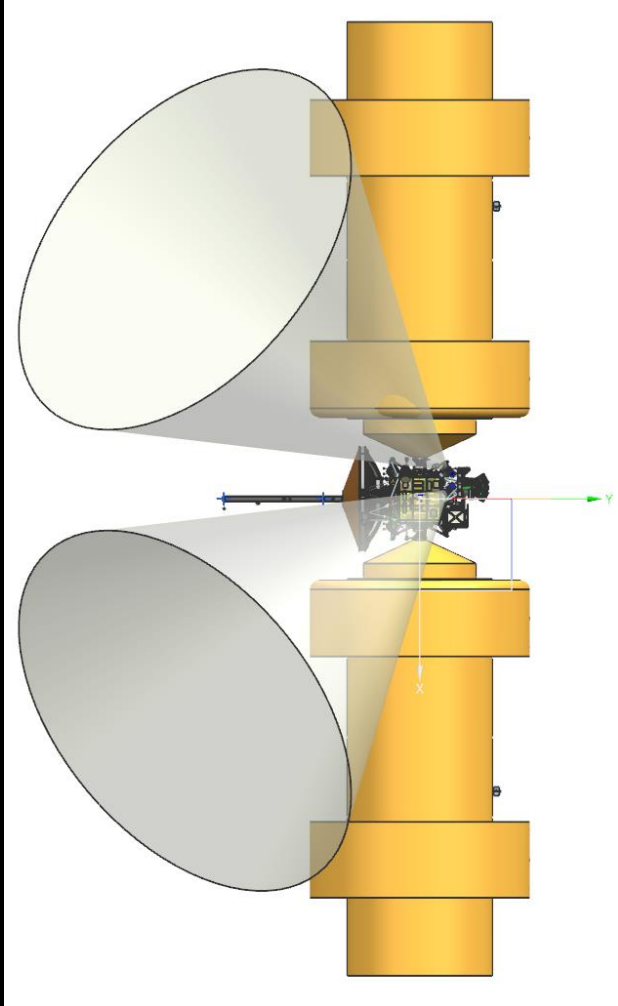
Lower Fairing Access Door
Prop Fill/Drain



SLS Block 1B
Fairing (option)



SA Updates: Impacts



SRU / SA Gimbal Envelop (Inner VHF Antenna)